VIRGINIA GEOLOGICAL SURVEY

UNIVERSITY OF VIRGINIA

THOMAS LEONARD WATSON, PH. D.
DIRECTOR

Bulletin No. VIII

Biennial Report

ON THE

Mineral Production of Virginia

During the Calendar Years

1911 and 1912

BY

THOMAS L. WATSON

WITH CHAPTERS ON

Zirconiferous Sandstone Near Ashland, Virginia

BY

THOMAS L. WATSON AND FRANK L. HESS

AND

Geology of the Salt and Gypsum Deposits of Southwestern Virginia

BY

GEORGE W. STOSE

VIRGINIA GEOLOGICAL SURVEY

UNIVERSITY OF VIRGINIA

THOMAS LEONARD WATSON, PH. D.
DIRECTOR

Bulletin No. VIII

Biennial Report

ON THE

Mineral Production of Virginia

During the Calendar Years

1911 and 1912

BY

THOMAS L. WATSON

WITH CHAPTERS ON

Zirconiferous Sandstone Near Ashland, Virginia

BY

THOMAS L. WATSON AND FRANK L. HESS

AND

Geology of the Salt and Gypsum Deposits of Southwestern Virginia

BY

GEORGE W. STOSE

CHARLOTTESVILLE
UNIVERSITY OF VIRGINIA
1913

J. P. BELL COMPANY
INCORPORATED
Printers
Designers
& Engravers
Lynchburg, Va.
Established 1859

STATE GEOLOGICAL COMMISSION

William Hodges Mann, *Chairman,*
Governor of Virginia.

E. A. Alderman,
President of the University of Virginia.

J. D. Eggleston,
President of the Virginia Polytechnic Institute.

E. W. Nichols,
Superintendent of the Virginia Military Institute.

G. P. Johnson,
General Manager of the C. & O. Railway.

Thomas Leonard Watson,
Director of the Survey.

CONTENTS

ILLUSTRATIONS

LETTER OF TRANSMITTAL

VIRGINIA GEOLOGICAL SURVEY,
UNIVERSITY OF VIRGINIA,
CHARLOTTESVILLE, October 15, 1913.

To His Excellency, Hon. Wm. Hodges Mann, Governor of Virginia, and Chairman of the State Geological Commission:

SIR:—I have the honor to transmit herewith for publication, as Bulletin No. VIII of the Virginia Geological Survey Series of Reports, a Biennial Report on the Mineral Production of Virginia during the Calendar Years 1911 and 1912, by Thomas L. Watson, with chapters on "Zirconiferous Sandstone Near Ashland, Virginia," by Thomas L. Watson and Frank L. Hess, and "Geology of the Salt and Gypsum Deposits of Southwestern Virginia," by George W. Stose.

Respectfully submitted,
THOMAS L. WATSON,
Director.

BIENNIAL REPORT ON THE MINERAL PRODUCTION OF VIRGINIA DURING THE CALENDAR YEARS 1911 AND 1912

BY THOMAS L. WATSON.

INTRODUCTION

This bulletin includes (1) a discussion of the mineral production of Virginia for the calendar years 1911 and 1912, (2) a description of the occurrence of zirconiferous sandstone near Ashland, and (3) a summary of the geology of the salt and gypsum deposits of southwest Virginia. The description of surface features of the State, given in Bulletins I-A and VI of the Survey, has been omitted in this report.

The statistics of mineral production in Virginia for the calendar years 1911 and 1912 were collected by the Virginia Geological Survey in coöperation with the United States Geological Survey. The total number of productive operations for the two years was large and included a variety of subjects, as indicated in the totals below of annual production.

The total value of the mineral industry in 1911 amounted to $19,320,970, and in 1912, $21,276,157, distributed as shown in the table on page 2.

With but few exceptions the returns indicate substantial gains in the products mined and quarried in the State. The total aggregate value of the mineral industry in 1912 showed an increase of $1,955,187 over that of 1911. The most noticeable increase was that of coal, and the most marked decrease was in iron ores.

The mineral products mined and quarried in Virginia in 1911 and 1912 are discussed in this report in the following order: Iron ores, manganese ores, gold and silver, copper, lead and zinc, tin, coal and coke, clay and clay products, lime and cement, sand and gravel, stone (granite, limestone, sandstone, slate, crushed stone, and furnace flux), abrasives (millstones), silica (diatomaceous earth), mica, feldspar, asbestos, talc and soapstone, bartyes, gypsum, salt, mineral paints, marl, pyrite and pyrrhotite, arsenic, rutile, and mineral waters.

Mineral Production of Virginia in 1911.

Product	Unit of Measurement	Quantity	Value
Clay products			$ 1,743,007
Coal	Short tons	6,864,667	6,254,804
Coke	Short tons	910,411	1,615,609
Copper	Pounds	90,000	11,250
Gold	Fine ounces (Troy)	148	3,064
Granite			420,611
Iron ores	Long tons	610,871	1,146,188
Iron, pig	Long tons	308,789	3,898,285
Lead	Short tons	415	37,374
Lime	Short tons	132,133	483,016
Limestone			369,872
Manganese ores	Long tons	2,455	24,546
Millstones			17,635
Mineral waters	Gallons	2,474,918	298,701
Pyrite	Long tons	150,800	558,494
Sand and gravel	Short tons	553,996	204,170
Sandstone			31,315
Silver	Fine ounces (Troy)	21	11
Slate	Squares	40,040	188,808
Talc and soapstone	Short tons	26,759	660,926
Zinc (spelter)	Short tons	1,032	117,695
Other products[a]			1,235,589
Total			$19,320,970

[a]Includes asbestos, bartyes, cement (Portland), feldspar, ferro-alloys, gypsum, diatomaceous earth, manganiferous ore, metallic paints, mica, ocher, and salt.

Mineral Production of Virginia in 1912.

Product	Unit of Measurement	Quantity	Value
Clay products			$ 1,884,743
Coal	Short tons	7,846,638	7,518,576
Coke	Short tons	967,947	1,815,975
Granite			470,657
Iron ores	Long tons	412,520	903,130
Iron, pig	Long tons	328,961	4,364,708
Lime	Short tons	124,711	488,628
Limestone			403,063
Manganese ore	Long tons	1,537	14,881
Metals (gold, silver, copper, lead, and zinc)			74,855
Millstones			25,866
Mineral waters	Gallons	2,762,319	349,255
Pyrite	Long tons	162,478	621,219
Sandstone			4,020
Sand and gravel	Short tons	689,266	291,773
Slate	Squares	42,220	195,392
Talc and soapstone	Short tons	25,313	576,473
Other products[a]			1,272,943
Total			$21,276,157

[a]Includes barytes, briquets (fuel), Portland cement, feldspar, ferro-alloys, gems and precious stones, gypsum, diatomaceous earth, manganiferous ore, ocher, metallic paint, rutile, and salt.

IRON ORES AND PIG IRON.

The production of iron ores in Virginia in 1911 and 1912, shows a decided falling off, both in quantity and value, from that of the two previous years, 1909 and 1910. The production in 1912 was the lowest of any single year during the last five-year period. It was 412,520 long tons, valued at $903,130, as compared with 610,871 long tons, valued at $1,146,188 in 1911, a decrease of 198,351 long tons in quantity and $243,058 in value.

The 1911 production of iron ores in the State represented the output from forty-two mines distributed among fourteen producers operating in the same number of counties (14); as against twenty-nine mines distributed among eight producers operating in ten counties in 1912.

The counties producing iron ore in Virginia during 1911 were: Alleghany, Augusta, Bedford, Botetourt, Carroll, Craig, Grayson, Lee, Page, Pittsylvania, Pulaski, Roanoke, Rockbridge, and Wythe. Those producing in 1912 were: Alleghany, Bedford, Botetourt, Craig, Lee, Pulaski, Roanoke, Rockbridge, Warren, and Wythe.

There is given in the table below the total production of iron ore in Virginia, by varieties, from 1908 to 1912, inclusive. It will be observed that brown hematite is vastly the most important variety, amounting at present to 88.5 per cent of the total production. Red hematite is next in order of importance, amounting to 11.5 per cent of the total production in 1912. The production of magnetite in 1911 was small; there being only one producer. There was no reported production of magnetite in 1912.

Production of Iron Ore in Virginia, by varieties, 1908-1912, in long tons.

Year	Brown hematite	Red hematite and magnetite	Total quantity	Total value
1908	626,910	65,313	692,223	$1,465,691
1909	762,937	74,910	837,847	1,693,188
1910	821,131	82,246	903,377	1,845,144
1911	541,870	69,001	610,871	1,146,188
1912	365,048	47,472	412,520	903,130

The average price per long ton of the different varieties of iron ore produced in Virginia during 1912 follows: Brown hematite $2.26, as against $1.91 in 1911 and $2.07 in 1910; red hematite $1.62, as against $1.58 in 1911 and $1.74 in 1910; and magnetite $1.50, being the same as the average value per ton of magnetite in 1910 and 1911. These prices represent the value of the ore at the mouth of the mine, and are taken directly from the replies of the producers.

Owing to the fact that there were less than three producers in most of the producing counties of iron ores during 1912, the production by counties can not be given. Named in the order of production the counties were: Botetourt, Wythe, Craig, Alleghany, Pulaski, Lee, Roanoke, Bedford, Rockbridge, and Warren.

On December 31, 1912, one furnace was building in Virginia, which will use mineral fuel; one was rebuilding; and in addition one coke furnace was partly erected.

The production of pig iron in Virginia during 1912 amounted to 328,961 long tons, valued at $4,364,708, as compared with 308,789 long tons, valued at $3,898,285 in 1911, and 444,976 long tons, valued at $6,150,000 in 1910.

There is given in the table below the production of pig iron in Virginia for the years 1905 to 1912, inclusive.

Production of Pig Iron in Virginia, by years, 1905-1912.

Year	Quantity Long tons	Value	Value per ton
1905	510,210	$7,540,000[a]	$14.78
1906	483,525	8,591,000[a]	17.77
1907	478,771	8,963,000	18.72
1908	320,458[b]	4,578,000	14.29
1909	391,134[b]	5,550,000	14.19
1910	444,976[b]	6,150,000	13.82
1911	308,789	3,898,285	12.62
1912	328,961[c]	4,364,708	13.27

aEstimated.
bBirkinbine, J. Personal communication.
cParker, E. W. Personal communication.

LIST OF IRON ORE PRODUCERS.

OPERATOR	OFFICE	MINE
Alleghany Ore & Iron Co	Iron Gate	Dixie, Oriskany
Barr Ore & Iron Corporation	Pittsville	Barr
Boone's Path Iron Co	Baltimore, Md.	Rose Hill Station
Crescent Iron Ore Co	New York, N. Y.	Crescent
Ivanhoe Furnace Co	Pittsburgh, Pa.	Bailey Crockett, Fries, Gregory, Ivanhoe
Longdale Iron Co	Longdale	Circle, Longdale
Lowmoor Iron Co. of Virginia	Lowmoor	Dolly Ann, Fenwick, Horse Mountain, Jordan
Oriskany Ore & Iron Corporation, Lessees Alleghany Ore & Iron Co	Iron Gate	Dixie
Paint Bank Ore Co	Paint Bank	Paint Bank
Princess Furnace Co	Glen Wilton	Callie, Wilton
Pulaski Iron Co	Pulaski	Arcadia, Clayton, Faris, Norma, Porter, Rustin, Tasker, Thomas, Tipton

OPERATOR	OFFICE	MINE
Seibel, H. J., Jr.	Happy Creek	Seibel
Virginia Iron, Coal & Coke Co.	Roanoke	Barren Springs Cedar Run Dewey Fenwick Grubb Hurst Little Wythe Percival Potts Valley Morris Reed Island Rich Hill Rustin Sanders Tasker Thaxton Trout
West End Furnace Co.	Roanoke	Greenville
Worrell, N. J.	Sylvatus	High Rock
Zinns Iron Mining Co.	Washington, Pa.	Marys Creek

MANGANESE ORES.

Virginia has always been the principal producer of manganese ores in the United States. The figures of production in 1912 were 1,537 long tons, valued at $14,881, as compared with 2,455 long tons, valued at $24,546 in 1911. The figures represent a small increase in 1911 over that of 1910, but a decrease in 1912. Notwithstanding this decrease Virginia, as heretofore, exceeded in output all other states combined.

In addition to the figures given above, 1,405 long tons of manganese ore were reported as stock on hand at the close of 1911, and 410 long tons at the close of 1912.

There were 6 producers in 1911, and 5 in 1912. The following 5 counties contributed to the 1911 production: Augusta, Campbell, Rockbridge, Rockingham, and Warren. In 1912 the producing counties were: Augusta, Campbell, Rockbridge, and Rockingham.

There are given in the table below the figures of production and value of manganese ores in Virginia from 1908-1912, inclusive.

Production and value of Manganese Ores in Virginia, 1908-1912.

Year	Quantity Long tons	Value	Average value per ton
1908	6,144[a]	$62,776	$10.22
1909	1,334[b]	14,725	10.70
1910	2,059[b]	18,509	8.98
1911	2,455	24,546	10.00
1912	1,537	14,881	9.68

aIn addition, 274 long tons of manganiferous iron ore were sold.
bIncludes small production of manganiferous ore.

Greater interest and activity were manifested in manganese mining in Virginia during 1912 than for several years past. The Piedmont Manganese Corporation, operating in Campbell County, and the Pittsburgh Manganese Company, operating near Elkton, were engaged chiefly in developing their mines preparatory for steady productions.

The production of manganiferous iron ores in 1912 is included under "Other Products," since it came from only two producers.

LIST OF MANGANESE PRODUCERS.

OPERATOR	OFFICE	MINE
Cox, Charles W., Assignee, Henry W. Poor & Co.	New York, N. Y.	Crimora
Evington Manganese Co.	Evington	Evington
Lucas, H. L.	Leesville	Leesville
Metal Mfg. Co. (Succeeded by Niess Waner Co.)	Elkton	Elkton
Niess-Waner Co.	Elkton	Elkton
Piedmont Manganese Corporation of Virginia	Lynchburg	10 miles east of Lynchburg
Schultz, F. W.	Baltimore, Md.	Midvale
Seibel, H. J., Jr., Prop., and L. G. Lackey, Supt.	Happy Creek and Philadelphia, Pa.	Happy Creek
Shenandoah Ore Co., Inc.	Stuarts Draft	Stuarts Draft (6 miles from)

GOLD AND SILVER.

The production of precious metals, gold and silver, in Virginia during the years 1911 and 1912, was variable, as indicated in the following figures: Gold in 1911 amounted to 148.22 fine ounces, valued at $3,064, as compared with 10.54 fine ounces, valued at $218 in 1912, a very marked decrease; silver 21 fine ounces, valued at $11 in 1911, against 982 fine ounces, valued at $604, in 1912.

In 1911, the gold and silver produced in Virginia was 105.26 fine ounces in quantity and $2,176 in value more than in 1910. Of the gold produced 39.09 fine ounces were derived from placers and 109.13 from siliceous ores; of the silver produced 7 fine ounces came from deep mines and 14 fine ounces from siliceous ores. Of the 13 properties producing, 5 were placers. According to McCaskey, 1,761 tons of gold quartz ores were treated with an average extraction value of $1.29 per ton.

In 1912, the gold production was derived entirely from siliceous ores. According to McCaskey 45 tons of Virginia siliceous ores were treated with an average precious metal recovery of $2.98 per ton. The silver production for the same year was derived from 1,160 short tons of copper ores. The 1912 production of precious metals in the State was derived from Fauquier, Goochland, and Prince William counties. No production from placer mining in the State was reported in 1912.

In Halifax County development work was in progress at the Poole gold mine and the erection of a stamp mill was contemplated.

In Spottsylvania County, the Holladay mine of mixed sulphides of lead, zinc, and iron with copper, and yielding small values in gold and silver, has been opened to a depth of 150 feet. The ore body, carrying large values in lead and zinc, has a width up to 20 feet and for the depth opened is a most encouraging prospect. The country rock is schist. In addition to the shaft some open-pit prospecting has been done, and in 1912 diamond drilling was in progress. Development work was also under way during 1912 by John M. Holladay and Son on the adjoining property, known as the Grindstone, which was worked for gold many years ago. The report[a] just issued by the Virginia Geological Survey on the gold deposits of the James River Basin, including the counties of Buckingham, Fluvanna, Goochland, and Cumberland, should revive interest in gold mining in that section of the State.

The following table, taken from Mineral Resources of the United States for 1912, shows the production of gold, silver, copper, lead, and zinc in Virginia for the years 1905 to 1912, inclusive.

Tonnage of ore treated and mine production of metals in Virginia, 1905-1912.

Year	Ore sold or treated	Gold[a]	Silver[a]	Copper	Lead	Zinc	Total value
	Short tons	*Value*	*Fine ounces*	*Pounds*	*Pounds*	*Pounds*	
1905	800	$ 4,982	177	....	....	....	$ 5,087
1906	1,000	14,832	250	....	....	....	15,000
1907	26,822	8,288	221	58,880	118,400	....	26,485
1908	12,877	2,451	236	24,775	76,190	1,410,961	75,361
1909	14,075	3,750	4,825	224,162	....	116,627	41,698
1910	16,976	888	128	5,402	198,850	1,588,112	96,151
1911	17,782	3,064	21	90,000	830,542	2,064,818	169,394
1912	5,790	218	982	111,835	469,026	497,235	74,855
Increase (+) or decrease (—) in 1912	—11,992	—2,846	961	+21,835	—361,516	—1,567,583	—94,539

[a]Includes placer gold and silver.

COPPER.

The production of copper in Virginia in 1911 was 90,000 pounds, valued at $11,250; and in 1912, 112,835 pounds, valued at $18,618, an increase of 32,835 pounds in quantity and $7,368 in value. The production in 1912 was derived from 1,160 short tons of copper ores and from mine

[a]Taber, Stephen. Geology of the Gold Belt in the James River Basin Virginia. Va. Geol. Survey, Bull. VII, 1913, 271 pages.

waters of the pyrite mines in Louisa and Prince William counties. There was no production of copper in 1912 reported from the mines of the Virgilina district in Halifax County. Annual statistics of copper production in Virginia for the years 1905 to 1912, inclusive, are given in the table on page 7.

LEAD AND ZINC.

There was an important production of both lead and zinc in Virginia in 1911 and 1912, but there was a marked decrease in both in 1912 from that of 1911. The figures are, according to McCaskey: Lead 830,542 pounds, valued at $37,374 in 1911, against 469,026 pounds, valued at $21,106 in 1912, a decrease of 361,516 pounds in quantity and $16,278 in value; zinc 2,064,818 pounds (figured as spelter), valued at $117,695 in 1911, as compared with 497,235 pounds, valued at $34,309 in 1912, a decrease of 1,567,583 pounds in quantity and $83,386 in value.

The Austinville, Bertha, and Little Wythe mines, in Wythe County, produced lead and zinc in 1912. McCaskey has summarized the 1912 production from this county as follows:[a] "The output is from both ore and old tailings, which are concentrated. A small tonnage of ore was also shipped crude. Part of the concentrates and soft ore were treated in the Austinville oxide plant and the remainder was shipped. At the Little Wythe mine, near Cripple Creek, the principal production is of iron ore, but as zinc sulphides are encountered in streaks they are mined, handsorted, and shipped crude to zinc smelters."

The annual statistics of lead and zinc production in Virginia for the years 1905 to 1912, inclusive, are given in the table on page 7.

TIN.

Though not a producer of tin, the existence of tin ore of excellent quality in the Irish Creek area of Rockbridge County has been known for many years, and in 1883 and later the deposits were opened in several places.

COAL.

The coal areas of Virginia which have produced or are producing are (1) the Richmond coal basin in the eastern border of the Piedmont

---

[a]Advance chapter from Mineral Resources of the United States, Calendar Year 1912, p. 21.

Plateau, and the only area of free-burning coal in the eastern portion of the United States that is located immediately adjacent to tidewater; and (2) the Appalachian region west of the Blue Ridge and which comprises a number of separate areas extending entirely across the State from Frederick County on the north to the Tennessee boundary on the south.

Geologically, the Virginia coal deposits are grouped as (1) those of Triassic age, including the Richmond coal basin, and (2) those of Carboniferous age, which includes all coal deposits found west of the Blue Ridge. Of the Carboniferous coal deposits, those of the Mountain Falls district, Frederick County; the North River area, Augusta County; the North Mountain area, Botetourt County; the Montgomery-Pulaski counties area; and the Bland-Wythe counties area are Mississippian (Lower Carboniferous) in age. The Virginia portion of the Appalachian coal field, which includes the extreme southwest counties along the borders of West Virginia and Kentucky, and to which the State owes its rank as a coal producer, is Pennsylvanian (Upper Carboniferous) in age.

The southwest Virginia area (Pennsylvanian), including the Pocahontas and Big Stone Gap coal fields, is estimated to contain 1,550 square miles. The Virginia Geological Survey in coöperation with the U. S. Geological Survey is engaged in systematic study, including detailed topographic and geologic mapping of this entire area, after the completion of which an elaborate report will be prepared and published by the State Geological Survey. The area comprises all or a part of the following counties: Buchanan, Dickenson, Lee, Russell, Scott, Tazewell, and Wise. Of these, Wise, Tazewell, and Lee counties are the most important producers at present. The other counties contain large reserves of coal which are rapidly undergoing development.

The mining of coal on an extensive scale in southwest Virginia began with the opening up of the Pocahontas field in 1883 and ten years later the development of the Wise County coal field. In 1905 the Black Mountain district of Lee County was made available, and the first shipments began in 1907. Lee County is now producing at the rate of 750,000 tons a year. The production has increased in Russell County from about 220,000 tons in 1908 to more than 1,200,000 tons in 1912.

Reopening of the old Gayton mines in Henrico County about four years ago has revived interest in coal mining in the Richmond basin, and a large tonnage was reported for each of the years 1911 and 1912.

The quantity and value of coal mined in Virginia in 1912, exceeded by nearly a million tons in quantity and more than one and a quarter

million dollars in value the production of any previous year. The figures were 7,846,638 short tons, valued at $7,518,576, an increase of 981,971 short tons in quantity, and $1,263,772 in value over 1911. More than 75 per cent of the total increase was from Wise County, whose production in 1912 was 4,500,174 short tons, against 3,754,360 short tons in 1911, a gain of 745,814 short tons, or nearly 20 per cent. In 1912, 47.7 per cent of the total coal mined was shot off the solid, and 35.6 in 1911. The number of machines increased from 156 in 1911 to 185 in 1912. Likewise the machine-mined coal increased from 2,551,627, or 37.1 per cent of the total, in 1911, to 3,205,504 tons, or 40.8 per cent, in 1912. The quantity of coal mined by hand in 1912 was 898,821 tons, as compared with 1,865,320 tons in 1911. The average price per ton of coal mined in Virginia in 1912 was 96 cents, against 91 cents in 1911.

The coal mining industry in Virginia during 1911 showed a very marked increase over the production for 1910, in which year it will be recalled the high-water mark was reached in the production of coal in the State. The figures of production were 6,864,667 short tons, valued at $6,254,804. Compared with the 1910 production, the increase in quantity was 356,670 short tons, and in value $377,318. The production in Wise County increased from 3,730,992 short tons in 1910 to 3,754,360 short tons in 1911; in Tazewell, from 1,187,146 short tons in 1910 to 1,281,224 short tons in 1911; and in Montgomery, from 7,699 short tons in 1910 to 8,462 short tons in 1911. The production in Lee County decreased from 797,096 short tons in 1910 to 720,695 short tons in 1911.

In order to avoid disclosing individual production, the figures for Henrico, Pulaski, and Russell counties are combined, and, for the same reason, it is not possible to compare the 1911 production in these three counties with that of the preceding year. The production of Henrico, Pulaski, and Russell counties combined was 1,098,594 short tons, valued at $996,209. The average price per ton in 1911 was 91 cents, as against 90 cents in 1910, and 89 cents in 1909. The number of mining machines increased from 142 in 1910 to 156 in 1911, and the machine-mined coal from 2,290,435 short tons in 1910 to 2,551,627 short tons in 1911, 27.2 per cent of the total quantity of coal mined in 1911.

The accompanying table gives the quantity and value of coal produced in Virginia from 1908 to 1912, inclusive.

Quantity and value of Coal produced in Virginia, 1908 to 1912, inclusive.

Year	Quantity (short tons)	Value
1908	4,259,042	$3,868,254
1909	4,752,217	4,251,056
1910	6,507,997	5,877,486
1911	6,864,667	6,254,804
1912	7,846,638	7,518,576

The production of coal by counties in 1911 and 1912 and its distribution for consumption are given in the tables below:

Coal production of Virginia in 1911 and 1912, in short tons.

1911

County	Loaded at mines for shipment	Sold to local trade and used by employees	Used at mines for steam and heat	Made into coke	Total quantity	Total value	Average price per ton	Average number of days active	Average number of employees
Lee	667,611	5,656	21,830	25,598	720,695	$ 724,498	$1.01	250	776
Tazewell	1,027,786	25,682	38,389	189,367	1,281,224	1,209,138	.94	210	1,352
Wise	2,470,449	39,769	89,343	1,154,799	3,754,360	3,301,984	.88	274	3,582
Other counties[a] and small mines	1,065,048	11,242	32,098	....	1,108,388	1,019,184	.92	279	1,682
Total	5,230,894	82,349	181,660	1,369,764	6,864,667	6,254,804	.91	261	7,392

1912

County	Loaded at mines for shipment	Sold to local trade and used by employees	Used at mines for steam and heat	Made into coke	Total quantity	Total value	Average price per ton	Average number of days active	Average number of employees
Lee	718,570	5,245	15,725	11,736	751,276	$ 875,092	$1.16	269	1,081
Tazewell	1,057,788	26,369	36,805	181,081	1,302,043	1,318,762	1.01	203	1,367
Wise	3,008,443	65,277	90,872	1,335,582	4,500,174	4,094,905	.91	261	4,451
Other counties[a] and small mines	1,242,911	10,766	39,468	....	1,293,145	1,229,817	.95	252	1,779
Total	6,027,712	107,657	182,870	1,528,399	7,846,638	7,518,576	.96	251	8,678

[a]Henrico, Montgomery, Pulaski, and Russell.

There is given in the table below the production of coal in Virginia from 1908 to 1912, inclusive, by counties.

Coal production of Virginia, 1908-1912, by counties, in short tons.

County	1908	1909	1910	1911	1912	Increase (+) or decrease (—) 1912
Lee	....	....	797,096	720,695	751,276	+ 30,581
Tazewell	980,014	975,665	1,187,146	1,281,224	1,302,043	+ 20,819
Wise	2,558,874	2,841,448	3,730,992	3,754,360	4,500,174	+ 745,814
Russell	[a]719,954	[a]931,276	[b]790,066	[b]1,107,056	[b]1,292,365	+ 185,309
Small mines	200	3,828	2,697	1,332	780	— 552
Total	4,259,042	4,752,217	6,507,997	6,864,667	7,846,638	+ 981,971
Total value	$3,868,524	$4,251,056	$5,877,486	$6,254,804	$7,518,576	+$1,263,772

[a]Includes Lee, Montgomery, and Pulaski counties.
[b]Includes Henrico, Montgomery, and Pulaski counties.

LIST OF COAL PRODUCERS.

OPERATOR	OFFICE	MINE
Beacham Coal Co	Christiansburg	Beacham
Big Town Hill Creek Coal Corporation	Richlands	Big Town Hill
Big Vein Pocahontas Coal Co	Pocahontas	Big Vein No. 1
Black Mountain Mining Co	Big Stone Gap	Kamont
Blacksburg Mining & Mfg. Co	Cambria	Snider Hill
Blackwood Coal & Coke Co	Blackwood	Blackwood, Pardee, and Roaring Fork
Blue Ridge Coal Co	Roanoke	Blue Ridge
Bond Coal Co	Tacoma	Greeno
Bondurant Coal & Coke Co	Pennington Gap	Bondurant
Bruce Coal & Coke Co	Coeburn	Bruce
Buchanan Lumber & Coal Co	Camden, N. J.	Prospect
Clinchfield Coal Corporation	Dante	Clinchfield, Cranes Nest, and Dante
Clinch River Coal Co	Richlands	Clinch River
Colonial Coal & Coke Co	Dorchester	Dorchester
Darby Coal Mining Co	Darbyville	Darby
Domestic Coal Co	Raven	Domestic
Dominion Coal Co	Pennington Gap	Mabel Edgar
Empire Coal Land Corporation	Alfredton	Seaboard
Esser Coal & Coke Co	Esserville	Esserville
Fleming & Co., Robert	Norton	Banner
Fork Ridge Coal Co	Asheville, N. C.	Greeno
Goodloe Bros. Co., Inc	Big Stone Gap	Pin Hook
Gray Coal Co	Pennington Gap	Jew
Hall & Robinett (Formerly N. E. Dickenson)	Coeburn	Dickenson
Huettel Coal Co	Norton	Huettel
Intermont Coal & Iron Co	Big Stone Gap	Josephine
Jewell Ridge Coal Corporation	Tazewell	Jewell Ridge
Kinzer & Son	Vicar Switch	Stroubles Creek
Lipps Coal Co	Wise	Lipps
Monarch Coal Co	Cincinnati, Ohio	Leona
Norton Coal Co	Norton	Norton No. 2
Old Dominion Development Co	Richmond	Carbon Hill
Pocahontas Consolidated Collieries Co	New York, N. Y.	Boissevain and Pocahontas
Pulaski Anthracite Coal Co	Parrott, and New York, N. Y.	Parrott
Raven Fuel Co	Red Ash (Raven)	Raven
Raven Red Ash Fuel Co	Red Ash	Red Ash
Slusser & Co., M. C	Blacksburg	Brush Mountain
Southern Anthracite Coal Co	Roanoke	Clear Air
Southern Pocahontas Coal Co	Richlands	Sater
Stonega Coke & Coal Co	Big Stone Gap	Arno, Imboden, Keokee, Osaka, Roda, and Stonega

OPERATOR	OFFICE	MINE
Stonegap Colliery Co	Glamorgan	Glamorgan
Sutherland Coal & Coke Co	Dorchester	Sutherland
Town Hill Coal Co	Bluefield, W. Va.	Town Hill
Virginia City Colliery Co	Virginia City	Virginia City
Virginia Iron, Coal & Coke Co	Roanoke	Imperial, Inman, Linden, Marion, Toms Creek
Virginia Lee Co., Inc	St. Charles	Virginia Lee
Virginia-Tennessee Coal Co	Knoxville, Tenn.	Coal Creek
Wise Coal & Coke Co	Dorchester	Wise
Yellow Creek Coal & Coke Co., Inc	Wise	Yellow Creek

COKE.

The coking coals of Virginia are confined to the coal-producing counties in the extreme southwestern part of the State. Development of the region began in 1883. Virginia is handicapped in the manufacture of coke by the fact that it has but few local markets for its product.

The production of coke in Virginia during 1912 amounted to 967,947 short tons, valued at $1,815,975, against 910,411 short tons, valued at $1,615,609 in 1911, an increase of 57,536 short tons, or 6.32 per cent, in quantity, and $200,366, or 12.4 per cent, in value.

The number of coke-making establishments was 18 for each of the years 1911 and 1912. The total number of ovens was reduced from 5,496 to 5,408, which represents an abandonment of 88 ovens during the year. There were 2,976 ovens in operation in 1912 and 2,273 in 1911. The average value of coke per ton in 1911 was $1.77, and in 1912, $1.88.

Of the 1911 production of coke (1,615,609 short tons) in Virginia, 759,789 short tons came from Wise County, with a value of $883,029. The other counties producing in 1911, listed in order of production, were: Tazewell, Lee, and Alleghany. Of the total coke production in 1912 (967,947 short tons), 843,474 short tons, valued at $1,572,633, came from Wise County. Named in order of production, the other counties producing in 1912 were: Tazewell, Alleghany, and Lee.

The statistics of the manufacture of coke in Virginia from 1908 to 1912, inclusive, are shown in the following table.

Statistics of the manufacture of Coke in Virginia, 1908-1912.

Year	Establishments	Ovens		Coal used (short tons)	Yield of coal in coke (per cent)	Coke produced (short tons)	Total value of coke at ovens	Value of coke at ovens per ton
		Built	Building					
1908	19	4,853	158	1,785,281	65.1	1,162,051	$2,121,980	$1.83
1909	19	5,469	100	2,060,518	65.1	1,347,478	2,415,769	1.79
1910	18	5,389	100	2,310,742	64.6	1,493,655	2,731,348	1.83
1911	18	5,496	100	1,425,303	63.9	910,411	1,615,609	1.77
1912	18	5,408	0	1,555,969	62.2	967,947	1,815,975	1.88

All the coal used in coke-making in Virginia is of exceptionally high grade and requires no preparation before charging into the ovens, save that of crushing. Hence, all the coal used in the manufacture of coke in the State during the years 1911 and 1912 was unwashed. Of the 1,425,303 short tons of coal made into coke during 1911, 749,806 were slack and 675,497 were run-of-mine. Of the total quantity of coal (1,555,969 short tons) used in the manufacture of coke in 1912, 762,950 short tons were unwashed slack and 793,019 short tons were unwashed run-of-mine.

The character of the coal used in coke-making in Virginia during the last five-year period (1908 to 1912) is shown in the table below.

Character of Coal used in the manufacture of Coke in Virginia, 1908-1912, in short tons.

Year	Run-of-Mine (Unwashed)	Slack (Unwashed)	Total
1908	1,438,754	346,527	1,785,281
1909	1,405,111	655,407	2,060,518
1910	1,554,784	755,958	2,310,742
1911	675,497	749,806	1,425,303
1912	762,950	793,019	1,555,969

LIST OF COKE PRODUCERS.

OPERATOR	OFFICE	MINE
Blackwood Coal & Coke Co	Blackwood	Blackwood
Colonial Coal & Coke Co	Dorchester	Dorchester
Empire Coal Land Corporation	Alfredton	Richlands
Intermont Coal & Iron Co	Big Stone Gap	Norton
Lowmoor Iron Co. of Virginia	Lowmoor	Covington and Lowmoor
Norton Coal Co	Norton	Norton
Pocahontas Consolidated Collieries Co., Inc.	Pocahontas	Pocahontas
Stonega Coke & Coal Co	Big Stone Gap	Imboden, Keokee, Osaka, and Stonega
Stonegap Colliery Co	Glamorgan	Glamorgan
Sutherland Coal & Coke Co	Dorchester	Dorchester
Virginia Iron, Coal & Coke Co	Roanoke	Appalachia and Toms Creek
Wise Coal & Coke Co	Dorchester	Dorchester

CLAYS AND CLAY PRODUCTS.

In 1911, the total value of all clay products in Virginia, including the value of pottery products, fire clay, and miscellaneous clay mined and sold in the State, amounted to $1,743,007, a decrease of $98,724 over 1910. The 1912 production amounted to $1,884,743 in value, an increase of $141,736, or 8.13 per cent over 1911. The principal clay

product in the State is common brick, with front brick ranking second, valued at $313,555 in 1912. Alexandria and Henrico are the two principal common brick-producing counties, with Washington, D. C., and Richmond their chief sources of supply.

The table on page 16 gives the statistics of clay products in Virginia from 1908 to 1912, inclusive. The item "Miscellaneous" in the table includes all products not otherwise specified, such as fire clay, pipe clay, clay for moulding, fancy or ornamental brick, fire brick, sewer pipe, and pottery products. In order to avoid disclosing individual production, it becomes necessary to combine these items under a single head.

From the accompanying table it will be seen that the total number of common and front brick manufactured in Virginia in 1911 was 240,067,000, valued at $1,688,640, distributed as follows: 219,035,000 common brick, valued at $1,374,439.00, and 21,032,000 front brick, valued at $314,201. The average value per thousand in 1911 was: Common brick, $6.27; front brick, $14.94.

The total number of common and front brick manufactured in Virginia in 1912 was 266,296,000, valued at $1,826,889, an increase of 26,229,000 in quantity, and $138,249 in value over the 1911 production. Of the 1912 production, 244,541,000 were common brick, valued at $1,513,338, and 21,755,000 front brick, valued at $313,551. The average value per thousand in 1912 was: Common brick, $6.19; front brick, $14.41.

The total number of fancy or ornamental brick and of fire brick produced in Virginia during 1911 and 1912 must be concealed in order to avoid disclosing figures of individual production. For the same reason it is not possible to give the production of common brick, by counties, during each of the years 1911 and 1912, except for the following counties: During 1911, Alexandria, 56,130 M, valued at $339,448; Augusta, 895 M, valued at $6,900; Henrico, 38,489 M, valued at $254,544; and Nansemond, 13,606 M, valued at $70,803; and during 1912, Alexandria, 53,671 M, valued at $294,590; Augusta, 653 M, valued at $4,885; Chesterfield, 12,144 M, valued at $71,459; Fairfax, 12,326 M, valued at $96,552; Henrico, 53,232 M, valued at $334,108; and Nansemond, 14,415 M, valued at $79,131.

Clay Products in Virginia from 1908 to 1912, inclusive.

Product	1908	1909	1910	1911	1912
Brick:					
Common—					
Quantity	185,738,000	249,791,000	229,982,000	219,035,000	244,541,000
Value	$1,219,946.00	$1,540,648.00	$1,460,160.00	$1,371,439.00	$1,513,338.00
Average per thousand	$6.57	$6.13	$6.35	$6.27	$6.19
Front—					
Quantity	17,858,000	24,717,000	20,813,000	21,032,000	21,755,000
Value	$246,623.00	$333,057.00	$291,348.00	$314,201.00	$313,551.00
Average per thousand	$13.81	$13.48	$14.14	$14.94	$14.41
Fancy or ornamental. Value	(a)	(a)	(a)	(a)	(a)
Fire. Value	(a)	(a)	$5,276.00	$10,875.00	$19,831.00
Drain tile. Value	$7,100.00	$6,298.00	(a)	(a)	(a)
Sewer pipe. Value	....	(a)	(a)	(a)	(a)
Pottery. Value	(a)	(a)	(a)	(a)	(a)
Miscellaneous. Value	$66,488.00	$77,364.00	$81,647.00	$43,492.00	$38,023.00
Total value	$1,540,157.00	$1,957,367.00	$1,841,731.00	$1,743,007.00	$1,881,743.00
Number of operating firms reporting	82	89	87	82	79

LIST OF CLAY PRODUCERS.

Brick and Tile.

OPERATOR	OFFICE	WORKS
Adams & Cannon	Blackstone	Blackstone
Adams Bros.-Paynes Co., Lynchburg Brick Works, Props	Lynchburg	Deacon
Adams, Payne & Gleaves, Inc	Roanoke	Roanoke
Alleghany Brick Co., Inc	Covington	Covington
Altavista Brick Co., Inc. (Formerly Frazier Lbr. Co.)	Altavista	Altavista
Baltimore Brick Co	Richmond	Rocketts
Barr, E. M	Winchester	Winchester
Billhimer, W. H	Harrisonburg	Harrisonburg
Blackburn & Lohr	Staunton	Staunton
Booker Brick Co	Morrison	Morrison
Boston Brick Co	South Boston	Houston and South Boston
Branson, Joseph	Staunton	Staunton
Brister & Turner	Petersburg	Ettricks
Brooks, A. M., & Son	New River	Radford
Bromilaw Brick Co	Alexandria	Alexandria
Buck, E. G., Recvr. Norton Brick and Mfg. Co	Norton	Norton
Buck. Levin T., & Co	Weems	Weems
Burroughs & Mankin, Inc	Richmond	Manbur
Champe, John A	Lexington	Lexington
Charlottesville Brick Co	Charlottesville	Charlottesville
Cheatwood & Blunt	Richmond	Richmond
Clarke & Covington	Culpeper	Elkwood
Clark & Crupper	Washington, D. C.	Arlington
Cole & Son, W. C. (Formerly Galax Brick Co.)	Galax	Galax
Covington Brick Co. (Formerly Isaac Clark)	Covington	Covington
Coyner, J. M	Basic City	Basic City
Croushorn, B. G., Lessee of H. V. Croushorn, Prop	Weyers Cave	Weyers Cave
Culpeper Brick Co	Culpeper	Elkwood
Davis, W. Benjamin, Brick Co., Inc	Richmond	Manchester
Dickinson Fire Brick Co	Buena Vista	Buena Vista
District of Columbia Workhouse, Brick Mfg. Dept	Occoquan	Lee District
Eureka Brick Co	Norfolk	Lynnhaven
Face, E. W., & Son	Norfolk	Norfolk
Fitzgerald, N. A. & T. J	Danville	Danville
Franklin Brick Co	Franklin	Franklin
Fulton Brick Works	Richmond	Richmond
Hoshour, John S., & Son	Woodstock	Front Royal and Woodstock
Holdaway, R. L	Major	Major
Hydraulic-Press Brick Co	Washington, D. C.	Waterloo
James River Brick Co., Inc	Norfolk	Sturgeon Point
Jones, W. L	Williamsburg	James City
Kenbridge Brick Co	Kenbridge	Kenbridge
Kincaid, B. F., & Son	Boones Path	Rose Hill
King Mountain Brick Co	Abingdon	Abingdon
Larson, A. C	Hampton	Suffolk
Lawrenceville Brick & Tile Co., Inc	Norfolk	Lawrenceville
Legg, John W	Stevensburg	Stevensburg
Lemley, L. F., & Sons	Strasburg	Strasburg
Mayo, W. R., & Sons	Norfolk	Sturgeon Point
Mulberry Island Brick Co	Newport News	Mulberry Island
Nansemond River Brick & Tile Co	Norfolk	Reid's Ferry
New Washington Brick Co	Washington, D. C.	Abingdon
Payne & Spindler	Drakes Branch	Drakes Branch
Pierpont Brick Works	Salem	Salem
Potomac Brick Co	Washington, D. C.	Addison
Potomac River Clay Works	Alexandria	Alexandria
Powers Bros. & Maynard	Richmond	Rocketts
Radford Brick Co	Philadelphia, Pa.	Tip Top
Ready, W. J	Richmond	Henrico and Manchester
Redford Brick Works	Richmond	Manchester
Richardson, R. H., & Son	Hampton	Chickahominy River

OPERATOR	OFFICE	WORKS
Richlands Brick Corporation	Norton	Richlands
Rosslyn Brick Co	Washington, D. C.	Rosslyn
Saint Paul Normal & Industrial School	Lawrenceville	Lawrenceville
Shrum Bros	Dayton	Dayton and Harrisonburg
Southern Brick Co. (Formerly Geo. J. Fletcher)	Fredericksburg	Fredericksburg
Southside Brick Co., Inc	Richmond	Barnes Siding
Suffolk Clay Co	Suffolk	Ladysmith
Sweet Briar Institute	Sweet Briar	Sweet Briar
Tip Top Brick Co	Tip Top	Tip Top
Travis, Frank M	New London	New London
Turner, W. R	Petersburg	Ettricks
Updike, Eston	Charlottesville	Charlottesville
Virginia Brick Co	Washington, D. C.	Relee
Virginia Brick Co	Suffolk	Suffolk
Virginia Brick Works	Richmond	East Fulton
Vulcan Fire Brick Co	Baltimore, Md.	Wilmont
Walker, W. T., Brick Co	Washington, D. C.	Arlington
Ward Brick Co	Galax	Galax
Washington Brick & Terra Cotta Co	Washington, D. C.	Riverside Park
Watson-Fitzgerald Corporation	Danville	Danville and Leaksville Junction
Waverly Brick Co., Inc	Petersburg	Waverly
West Bros. Brick Co	Washington, D. C.	Relee
West End Brick Yard (W. J. Ready, Prop.)	Richmond	Henrico and Manchester
Williamson, Hedgecock & Fontaine, Inc	Martinsville	Fontaine
Wood, Dr. Geo. B	Emporia	Emporia

CLAY MINED AND SOLD.

OPERATOR	OFFICE	MINE
Branch, John P	Richmond	City Point
Dickinson Fire Brick Co	Buena Vista	Buena Vista
Vulcan Fire Brick Co	Baltimore, Md.	Wilmont
Wills, T. L	Reusens	East Reusens

POTTERY.

OPERATOR	OFFICE	MINE
Akron Smoking Pipe Co	Mogadore, Ohio	Pamplin City
Powhatan Pipe Co	Michaux	Michaux
Shenandoah Pottery Co., Ltd	Broadway	Broadway

LIME.

The production of lime in Virginia during 1911, amounting to 132,133 short tons valued at $483,016, came from 44 producers distributed among the following 13 counties: Augusta, Botetourt, Frederick, Giles, Loudoun, Montgomery, Rockbridge, Rockingham, Russell, Shenandoah, Tazewell, Warren, and Washington.

The production of lime in Virginia during 1912 amounted to 124,711 short tons, valued at $488,628. These figures, when compared with the figures of production during 1911, represent a decrease of 7,422 short tons in quantity, but an increase of $5,612 in value. There were 45 producers of lime in the State during 1912, and the production was distributed among the following 13 counties: Augusta, Bath, Botetourt, Frederick, Giles, Loudoun, Montgomery, Rockbridge, Rockingham, Russell, Shenandoah, Tazewell, and Warren.

There are given in the table below the production and value of lime in Viriginia during 1911 and 1912, by counties.

Production and value of Lime in Virginia in 1911 and 1912, by counties.

County	1911 Production Short tons	1911 Value	1912 Production Short tons	1912 Value
Augusta	3,348	$ 10,602	2,320	$ 8,114
Botetourt	22,824	85,463	20,590	74,587
Frederick	(a)	(a)	26,448	104,520
Rockingham	3,676	13,419	3,042	12,239
Shenandoah	41,418	157,067	37,021	130,053
Other counties	60,867[b]	216,465[b]	35,290[c]	159,115[c]
	132,133	$483,016	124,711	$488,628

aIncluded under other counties.
bIncludes Frederick, Giles, Loudoun, Montgomery, Rockbridge, Russell, Tazewell, Warren, and Washington counties.
cIncludes Bath, Giles, Loudoun, Montgomery, Rockbridge, Russell, Tazewell, and Warren.

In the table below is given the production of lime in Virginia in 1911 and 1912, by uses.

Production of Lime in Virginia during 1911 and 1912, by uses, in short tons.

	1911 Quantity	1911 Value	1912 Quantity	1912 Value
Building lime	63,567	$237,078	68,284	$272,859
Hydrated lime	(a)	(a)	(a)	(a)
Paper mills	15,620	59,983	(b)	(b)
Fertilizer	32,655	104,688	32,702	116,381
Tanneries	4,109	15,657	1,865	6,378
Chemical works	(b)	(b)	(b)	(b)
Dealers—uses not specified	11.149	48,000	4,000	15,000
Miscellaneous[c]	5,033	17,610	17,860	78,010
	132,133	$483,016	124,711	$488,628

aOnly a small quantity of the lime produced in Virginia is hydrated.
bIncluded under miscellaneous.
cIncludes lime for chemical works and other purposes in 1911, and lime for paper mills, chemical works, and other purposes in 1912.

LIST OF LIME PRODUCERS.

OPERATOR	OFFICE	KILN
Barley, Louis C	Alexandria	28 miles w. of Staunton
Blankenship, S. M	Deerfield	Deerfield
Bristol Lime & Stone Co., Inc	Bristol, Va.-Tenn.	Benhams
Brown, C. H	Stuarts Draft	Stuarts Draft
Conner, I. N	Vaucluse Station	Vaucluse Station
Cooper, I. C	Hinton	Hinton
Cupp, G. V	Spring Creek	Spring Creek
Cupp, Stewart	Spring Creek	Spring Creek
Davis, C. W	Blacksburg	Blacksburg
Dillon's, E., Sons	Indian Rock	Indian Rock
Driver, Ira R	Mount Sidney	Mount Sidney
Eagle Rock Lime Co	Eagle Rock	Eagle Rock
Eureka Lime Co	Vicar Switch	Vicar Switch
Fellsworth Lime Works	Staunton	Staunton
Fiber, John W	Spring Creek	Spring Creek
Fifer, John	Spring Creek	Spring Creek
Grove, M. J., Lime Co	Limekiln, Md.	Stephens City
Harris, J. A	Stuarts Draft	Stuarts Draft
Harris, J. W	Stuarts Draft	Stuarts Draft
Hess, S. L	Spring Creek	Sangerville
Hogshead, Chas. A	Mossy Creek	Mossy Creek
Kiracofe, C. S	Bridgewater	Bridgewater
Leesburg Lime Co., Inc	Leesburg	Leesburg
Limeton Lime Co	Limeton	Limeton
Linville Lime Co	Linville	Linville
McClure, J. D	Startannery	Startannery
McIlwee, C. E	Zepp	Zepp
McKimmy, A. G	Lucketts	Lucketts
Michael, J. W	Spring Creek	Sangerville
Miller, E. E	Bridgewater	Bridgewater
Miller, G. E	Bridgewater	Bridgewater
Moore Lime Co	Richmond	Eagle Mountain
Natural Bridge Lime Co	Glasgow	Sherwood
New River Lime Co	Ripplemead	Ripplemead
Oak Ridge Lime Firm	Mt. Solon	Mt. Solon
Orndorff, M. M	Oranda	Oranda
Oyler, Geo. V	Winchester	Winchester
Powhatan Lime Co	Strasburg	Strasburg
Pullins, A. C	Mt. Sidney	Mt. Sidney
Riverton Lime Co	Riverton	Riverton
Rockbridge Lime & Stone Co	Lexington	Lexington
Rockdale Lime Co	Toms Brook	Toms Brook
Rowe, O. F	Deerfield	Deerfield
Rusmiselle, J. A	Mt. Solon	Mt. Solon
Shenandoah Lime Co	Strasburg Jct.	Strasburg Jct.
Standard Lime & Stone Co	Strasburg	Strasburg
Staunton, City of	Staunton	Staunton
Strasburg Lime Co	Strasburg	Strasburg
Stuart Land & Cattle Co	Elk Garden	Elk Garden
Tazewell White Lime Works	North Tazewell	North Tazewell
Thompson, T. W	Hinton	Harrisonburg
Wheelbarger-Rumsey Lime Corporation	Dayton	Dayton

CEMENT.

There are only two plants for the manufacture of Portland cement in Virginia, namely, that of the Virginia Portland Cement Company at Fordwick, Augusta County, and that of the Norfolk Portland Cement Corporation at Norfolk. The Fordwick plant has a capacity of 1,250,000 barrels, and is selling the Old Dominion cement in the North as well as in the South. The materials used by this plant in the manufacture of Old Dominion cement are Lewistown limestone and shale. The Norfolk plant is the first plant built in the South to manufacture Portland cement from shell marl as the principal calcareous material instead of the hard

rock—limestone. The marl and clay deposits used by this plant are located on branches of James River near Smithfield and Chuckatuck.

Inasmuch as there were only two plants in Virginia producing Portland cement in 1911, the figures of production are combined with those of another subject in order to avoid disclosing individual operations. The same condition holds for the 1912 production.

LIST OF CEMENT PRODUCERS.

OPERATOR	OFFICE	PLANT
Norfolk Portland Cement Corporation	Philadelphia, Pa.	Norfolk
Virginia Portland Cement Co	New York, N. Y.	Fordwick

SAND AND GRAVEL.

The production of sand and gravel in the State during 1912 amounted to 689,266 short tons, valued at $291,773, as compared with 553,996 short tons, valued at $204,170, in 1911. These figures represent an increase over the 1911 production of 135,270 short tons in quantity, and $87,603 in value.

In 1911, there were 31 producers, operating in 20 counties. The production by counties, during 1911, was as follows: Giles, 20,209 short tons, valued at $11,397; Henrico, 11,750 short tons, valued at $11,853; Rockingham, 25,905 short tons, valued at $8,465; Spottsylvania, 286,490 short tons, valued at $75,020; and other counties,[a] 209,642 short tons, valued at $97,435.

In 1912, there were 31 producers, operating in 21 counties. The production by counties, during 1912, was as follows: Giles, 5,878 short tons, valued at $3,074; Henrico, 10,716 short tons, valued at $9,366; Roanoke, 18,533 short tons, valued at $8,936; Rockingham, 12,080 short tons, valued at $9,718; Spottsylvania, 216,987 short tons, valued at $82,630; and other counties,[b] 425,072 short tons, valued at $178,049.

The following table shows the details of the industry, and the comparative quantities and values from 1908 to 1912, inclusive.

---

aIncludes Alexandria, Alleghany, Augusta, Campbell, Caroline, Charles City, Dinwiddie, Elizabeth City, New Kent, Norfolk, Princess Anne, Pulaski, Roanoke, Scott, Shenandoah, and Wythe.

bIncludes Alexandria, Alleghany, Augusta, Campbell, Caroline, Charles City, Dinwiddie, Elizabeth City, Hanover, New Kent, Norfolk, Pittsylvania, Princess Anne, Pulaski, Wise, and Wythe.

Production of Sand and Gravel in Virginia, 1908-1912, by uses, in short tons.

	1908		1909		1910		1911		1912	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Sand—										
Glass	....	....	....	....	700	$ 450	(a)	(a)	(a)	(a)
Molding	47,888	$ 22,568	25,180	$ 17,211	35,517	24,954	41,533	$ 18,303	21,701	$ 11,746
Building	139,742	61,378	368,741	125,208	251,170	88,340	216,756	98,675	374,894	164,456
Fire	....	....	....	....	....	....	(a)	(a)	(a)	(a)
Engine	6,651	2,860	3,591	1,585	1,900	1,165	7,843	3,220	(a)	(a)
Furnace	11,295	5,500	9,740	1,563	5,339	2,088	11,607	6,270	....	....
Other	670	325	17,631	8,149	22,494	10,628	23,500	3,775	9,595	4,279
Paving	....	....	....	....	....	....	11,079	4,275	12,250	2,688
Miscellaneous[b]	....	....	....	....	....	....	3,240	3,230	35,524	21,132
Gravel	242,988	26,464	392,287	124,431	147,201	87,791	238,438	66,422	235,302	87,472
Total	449,234	$119,095	847,176	$281,177	764,321	$215,416	553,996	$204,170	689,266	$291,773

[a]Included under miscellaneous.
[b]Includes glass sand, fire sand, grinding and polishing sand, and engine sand.

LIST OF SAND AND GRAVEL PRODUCERS.

OPERATOR	OFFICE	PIT OR BED
Appomattox Iron Works	Petersburg	Petersburg
Bickford Sand & Gravel Co	Hampton	Hampton
Botto, J. L., Sand Co	Richmond	Richmond
Bromilaw Brick Co	Alexandria	Alexandria
Calhoun, James W., & Bro	North River	North River
Clinedinst, J. S	Edinburg	Edinburg
Columbia Granite & Dredging Co	Washington, D. C.	Potomac River
Cooper Glass & Silica Co	Salem	Salem
Cowardin, S. P	Richmond	Richmond
Cuddy, W. T	Lurich	Lurich
Curlis, H. C	Holdcroft	Holdcroft
Dills, M. C	Bluff City	Pearisburg
Ellis, Atwell C	Lyndhurst	Lyndhurst
French, J. E., & Bro	Curve	Curve
French, K. S. (Sold to White Sand Co.)	Narrows	Narrows
Harbaugh, S. L., Mrs	Richmond	Richmond
Hunter, C. E., Farmers' Friend Plow Works	Fredericksburg	Fredericksburg
Lillie, George W	Richmond	Massaponax
Lowmoor Iron Co. of Virginia	Lowmoor	Lowmoor
Mercer & Miller	Richmond	Richmond
Monger, J. H	North River	Harrisonburg
National Mfg. Co., Inc	Lynchburg	Lynchburg
Norfolk Sand & Gravel Corporation	Norfolk	Hampton
Norfolk & Southern Ry. Co	Norfolk	Cape Henry
Laughon, B., & Co	Pulaski	Delton (Laughon Siding)
Port Republic Foundry	Port Republic	Port Republic
Quarles, A. G	Richmond	Richmond
Reynolds White Sand Co	Bristol	Bristol
Richmond, Fredericksburg & Potomac Ry. Co	Richmond	Fredericksburg
Shepherd, Larkin	Appalachia	Appalachia
Southern Sand & Gravel Co	Richmond	Fredericksburg
Summerman, Thomas H	Ivanhoe	Ivanhoe
Water Works Supply Corporation	Norfolk	Norfolk
Webb, J. H	Roanoke	Roanoke
Wills, T. L	Lynchburg	Lynchburg

STONE.

The stone industry in 1912 was third in importance among those based upon the mineral wealth of the State, being surpassed only by the coal and clay products. The total production exceeded in value that of the iron ores. The value of the annual production of stone in Virginia from 1908 to 1912 is given in the accompanying table.

Value of the annual production of Stone in Virginia from 1908-1912, inclusive.

Year	Granite	Sandstone	Slate	Limestone	Total
1908	$321,530	$ 2,600	$194,356	$280,542	$ 799,028
1909	488,250	28,574	180,775	342,656	1,040,255
1910	503,106	25,080	148,721	471,903	1,148,810
1911	420,611	31,315	188,808	369,872	1,010,606
1912	470,657	4,020	195,392	402,313	1,072,382

The total value of the different kinds of stone quarried for the period of years for which statistics are given, shows that the quarrying of granite

is the largest industry in stone, with limestone next, and slate third. The production of sandstone for the period represented in the table is relatively unimportant.

The value of the total production of stone in the State during 1912 was $1,072,382, against $1,010,606 in 1911, an increase in value of $61,776.

Granite.

The production of granite in the State during 1911 was valued at $420,611, against $503,106 in 1910, a decrease in value of $82,495, or nearly 16.4 per cent. Twenty-eight producers distributed among 16 counties contributed to this production. The counties were: Campbell, Chesterfield, Dinwiddie, Fairfax, Fluvanna, Goochland, Greenesville, Henrico, Loudoun, Lunenburg, Mecklenburg, Nelson, Pittsylvania, Prince William, Spottsylvania, and Stafford.

The value of the granite production in 1912 was $470,657, which represents an increase in value of $50,046 over the 1911 production. There were 15 counties producing in 1912, namely, Alexandria, Campbell, Chesterfield, Dinwiddie, Fairfax, Fluvanna, Goochland, Greenesville, Henrico, Loudoun, Lunenburg, Nelson, Pittsylvania, Prince William, and Stafford, and the output was distributed among 25 producers.

There are given in the table below the value and uses of the granite and gneiss quarried in Virginia during the years 1908 to 1912, inclusive.

Value of Granite produced in Virginia, 1908-1912, by uses.

Use	1908	1909	1910	1911	1912
Sold in the rough—					
Building	$ 26,769	$ 24,965	$ 31,841	$ 9,580	$ 28,617
Monumental	12,664	1,966	3,771	8,990	8,820
Other	1,075	....	2,375	(a)	....
Dressed for building	4,000	17,750	14,750	11,948	3,852
Dressed for monumental work	29,803	9,449	6,300	(a)	7,526
Made into paving blocks	10,173	18,053	28,596	32,458	79,046
Curbing	6,130	29,100	57,511	24,149	16,774
Flagging	....	990	1,565	(a)	(a)
Rubble	18,270	33,321	38,792	27,870	32,554
Riprap	16,336	1,386	6,989	(a)	59,575
Crushed stone—					
Road-making	21,670	74,054	40,691	39,379	54,540
Railroad ballast	92,895	125,704	111,811	145,722	49,480
Concrete	81,745	147,112	156,894	104,945	115,427
Other	....	4,400	1,220	(a)	(a)
Miscellaneous[b]	....	....	....	15,570	14,446
Total	$321,530	$488,250	$503,106	$420,611	$470,657

aIncluded under miscellaneous.
bIncludes dressed for monumental work, flagging, and other purposes.

There was a very marked increase in the number and value of granite paving blocks produced in the State in 1912.

The table below gives the number of granite paving blocks produced in Virginia, by years, from 1908 to 1912, inclusive.

Number and value of Granite Paving Blocks produced in Virginia, 1908-1912.

Year	Number	Value	Average Value per 1,000
1908	252,910	$10,173	$40.22
1909	853,300	18,053	21.16
1910	680,602	28,596	42.02
1911	872,710	32,458	37.19
1912	1,980,943	79,046	44.95

LIST OF GRANITE PRODUCERS.

OPERATOR	OFFICE	QUARRY
American Stone Co., Inc	Richmond	Kora
Andrews, J. W., & Co	Petersburg	Petersburg
Belmont Trap Rock Co., Inc	Herndon	Belmont Park
Cartwright & Davis	Fredericksburg	Fredericksburg
Columbia Granite & Dredging Co	Washington, D. C.	Washington, D. C.
Consolidated Quarry Co	Washington, D. C.	Occoquan (near)
Danville, City of	Danville	Danville
District of Columbia, Eng. Commissioner of	Washington, D. C.	Occoquan
Electric Generating Co	Fredericksburg	Falmouth (near)
Frazier Stone Co	Richmond	Greenway
Gregory, Lucius	Chase City	Chase City
Harris, H. J	Richmond	Boscobel (Harris Siding)
James River Granite Co	Richmond	Holland Siding
Jones, H. D., Rock Co	Lynchburg	Lynchburg
Lane Bros. Co	Altavista	Altavista
Logan, A	Lynchburg	Lynchburg
Lone Jack Stone Co. (Gneiss)	Lynchburg	Lynchburg
McCloy, John A., Granite Co	Richmond	Richmond
McGowan, John	Richmond	Manchester
Markley, C	Roanoke	Kenbridge
Miller & Kirkpatrick	Petersburg	Petersburg
Netherwood, Albin	Richmond	Richmond
Norfolk County Road Board	Skippers	Hitchcock (near Emporia)
Old Dominion Iron & Nail Works	Richmond	Richmond (Belle Isle)
Petersburg Granite Co	Baltimore, Md.	Petersburg
Smith, Charles G., & Son	Washington, D. C.	Washington, D. C. (near)
Smith, I. J., & Co,, Inc	Richmond	Richmond
Strathmore Quarrying Co	Richmond	Shores
Sunnyside Granite Co., Inc	Richmond	Dunbarton Station
Virginia Granite Co	Richmond	Dunbarton Station
Virginia State Farm	Lassiter	Lassiter
Washington Stone Co	Washington, D. C.	Occoquan
Wray, A. J	Richmond	Granite

Limestone.

The production of limestone in Virginia during each of the years 1911 and 1912 was below that of 1910, but the 1912 production showed a

marked increase over that of 1911. The value of the production in 1912 was $403,063, against $369,872 in 1911, an increase of $33,191, or 8.2 per cent.

There were 34 producers of limestone during 1911, operating in 16 counties as follows: Alleghany, Augusta, Botetourt, Giles, Loudoun, Montgomery, Roanoke, Rockbridge, Rockingham, Russell, Shenandoah, Smyth, Tazewell, Washington, Wise, and Wythe. There were 33 producers of limestone in Virginia in 1912, the production coming from the same counties as in 1911, except that Montgomery and Russell counties had no production, and there was one additional county, Warren, producing.

The production of limestone in Virginia from 1908 to 1912, inclusive, and the uses for which it was quarried are given in the table below:

Production of Limestone in Virginia, from 1908 to 1912, by uses.

	1908	1909	1910	1911	1912
Rough building	$ 1,870	$ 715	$ 125	$ (a)	$ 5,707
Dressed building	2,950	129			
Paving		15	45	(a)	
Curbing	79		750		
Flagging	110	7			
Rubble		3,000	3,188		(a)
Riprap	3,377		1,805		
Crushed stone:					
Road-making	30,159	31,076	20,056	42,643	56,500
Railroad ballast	45,541	84,883	108,129	126,884	115,576
Concrete	26,604	8,068	36,849	40,677	41,192
Flux	169,847	213,444	294,668	143,099	130,916
Agricultural				4,555	20,992
Unspecified	5	1,319	6,288	431	300
Miscellaneous				11,583[b]	31,880[c]
Total	$280,542	$342,656	$471,903	$369,872	$403,063

aIncluded under miscellaneous.
bIncludes rough building, paving, and alkali works.
cIncludes alkali works, paper mills, rubble, and small production of marble.

LIST OF LIMESTONE PRODUCERS.

OPERATOR	OFFICE	QUARRY
Alleghany Lime Co., Inc	Christiansburg	Houchin Station
Alleghany Ore & Iron Co	Iron Gate	Bells Valley
Bristol Lime & Stone Co., Inc	Bristol, Va.-Tenn.	Benhams (near)
Bunn & Co	Big Stone Gap	Big Stone Gap
Boxley, W. W	Roanoke	Sinking Creek
Clark County Construction Co	Big Stone Gap	Big Stone Gap
Cooper, I. C	Hinton	Hinton
Crigger, R. C	Wytheville	Wytheville
Culbert, W. F	Marion	Marion
Dillon's Sons, E	Indian Rock	Buchanan and Indian Rock
Eagle Rock Lime Co	Eagle Rock	Eagle Rock

OPERATOR	OFFICE	QUARRY
Fellsworth Lime Works	Staunton	Staunton
Fisher & Co., S. E	Strasburg	Strasburg Jct.
Fishersville Lime Grinding Co	Fishersville	Fishersville
Ivanhoe Furnace Co	Ivanhoe	Ivanhoe
Kinzer & Vermillion	Tazewell	Tazewell
Larner & Co., William	Staunton	Staunton
Leesburg Lime Co., Inc	Leesburg	Leesburg
Limeton Lime Co	Limeton	Limeton
Longdale Iron Co	Longdale	Longdale
Lowmoor Iron Co. of Virginia	Lowmoor	Lowmoor
Markley, C	Roanoke	Roanoke
Mathews Curtis Co., Inc	Clifton Forge	Clifton Forge
Moore Lime Co	Richmond	Eagle Rock
Natural Bridge Lime Co	Glasgow	Sherwood
Oriskany Ore & Iron Corporation	Iron Gate	Bells Valley
Paxton, C. H	Natural Bridge	Natural Bridge
Peters Co., R. L	Big Stone Gap	Big Stone Gap
Powhatan Lime Co	Strasburg	Strasburg
Pulaski Iron Co	Pulaski	Patterson and Ivanhoe
Riverton Lime Co	Riverton	Riverton
Rockbridge Lime & Stone Co	Lexington	Lexington
Rockdale Lime Co	Toms Brook	Toms Brook
Rule, W. R	Abingdon	Abingdon and Elk Garden
Staunton, City of	Staunton	Staunton
Stuart Land & Cattle Company	Elk Garden	Elk Garden
Vaughan Construction Co	Roanoke	Radford and Roanoke
Virginia Iron, Coal & Coke Co	Roanoke	Barren Springs, Buchanan, and Radford
Wells, John S	Staunton	Staunton
Wytheville Town Quarry	Wytheville	Wytheville

Sandstone.

The production of sandstone in Virginia is slight, and it varies greatly according to the local demands. The production in 1912 was valued at $4,020, as compared with $31,315 in 1911, a decrease of $27,295. There were 3 producers during 1912, and 5 during 1911. The value of the annual production of sandstone in the State from 1908 to 1912, inclusive, is shown in the accompanying table.

Value of Sandstone production in Virginia, 1908-1912.

Year	Value
1908	$ 2,600
1909	28,574
1910	25,080
1911	31,315
1912	4,020

LIST OF SANDSTONE PRODUCERS.

OPERATOR	OFFICE	QUARRY
Galther Construction Co	Manassas	Nokesville
Hall, L. M	Wise	Wise
Mathews Curtis Co., Inc	Clifton Forge	Basic City
Peak Creek Sandstone Co	Pulaski	Pulaski
Warden & Hailley	Pulaski	Pulaski

Slate.

There are five principal slate areas in Virginia, which, named in the order of their commercial importance, are: (1) The Arvonia belt in Buckingham and Fluvanna counties; (2) the Keswick-Esmont belt in Albemarle County; (3) the Snowden belt in Amherst and Bedford counties; (4) the Warrenton belt in Fauquier and Culpeper counties; and (5) the Quantico belt in Spottsylvania, Stafford, and Prince William counties. These are shown on map, fig. 1. The production during the years 1911 and 1912 was from the Arvonia and Keswick-Esmont belts.

In 1912, Virginia ranked fourth among the slate-producing states. The productive quarries are at Esmont, Albemarle County, and Arvonia and Penlan, Buckingham County. The product from these quarries is used exclusively for roofing.

The total production of slate in 1912 was 42,220 squares, valued at $195,392, as compared with 40,040 squares, valued at $188,808 in 1911, an increase of 2,180 squares in quantity and $6,584 in value. The average price per square in 1912 was $4.63 and in 1911, $4.72, a decrease of $0.09 per square. In 1911, there were 7 producers of slate operating in two counties, namely, Albemarle and Buckingham, as against 8 in the same counties in 1912, with the principal part of the production for each year from Buckingham County.

The amount and value of the annual production of slate in Virginia from 1908 to 1912, inclusive, are given in the accompanying table.

Production of Slate in Virginia, 1908-1912.

Year	Roofing Slate Number of Squares	Value	Average Price Per Square
1908	41,678	$194,356	$4.66
1909	40,880	180,775	4.42
1910	31,787	148,721	4.68
1911	40,040	188,808	4.72
1912	42,220	195,392	4.63

The number of squares, as given in the above table, includes both first and second qualities, and the average price per square does not give a fair indication of the prices obtained for most of the stock.

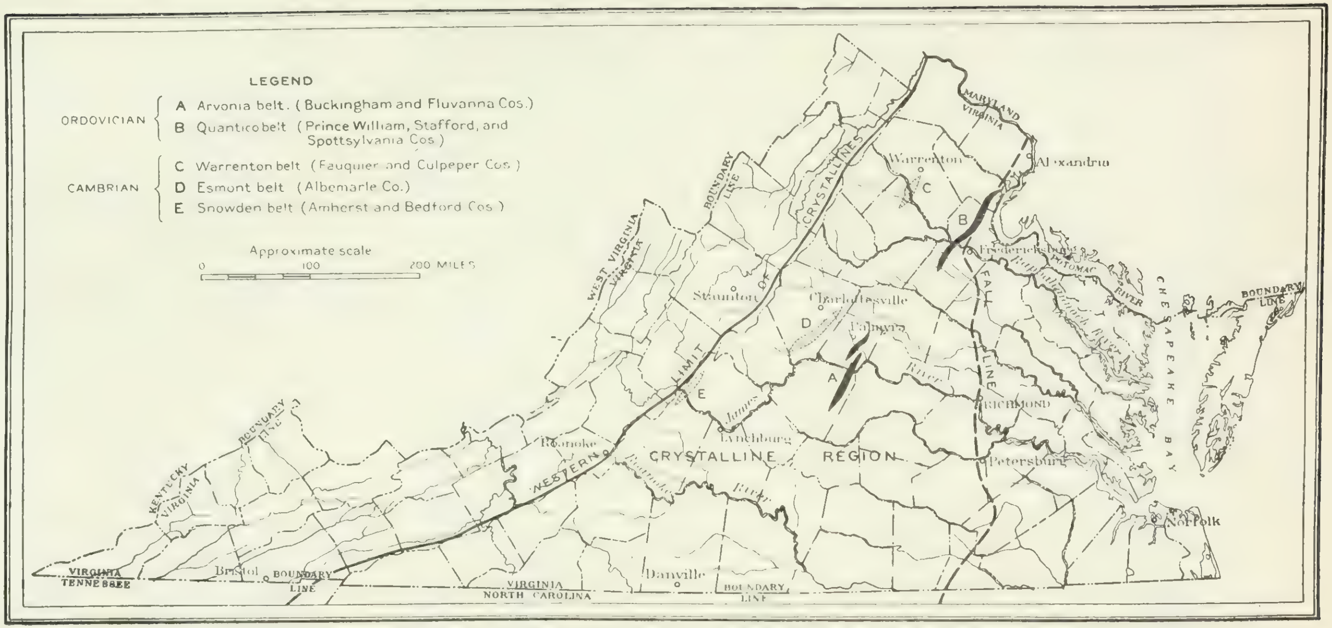

Fig. 1.—Map of Virginia showing location of slate belts.

LIST OF SLATE PRODUCERS.

OPERATOR	OFFICE	QUARRY
Buckingham Slate Co., Inc.	Richmond	Arvonia
LeSeuer Slate Co., Inc.	Orebank	Arvonia
National Slate Corporation of Virginia (Formerly New York & Buckingham Slate Co.)		Wealthia
Penlan Slate Co.	Penlan	Penlan
Pitts Slate Co., A. L.	Arvonia	Arvonia
Richmond Slate Co., Inc.	Richmond	Arvonia
Standard Slate Corporation	Esmont	Esmont
Williams Slate Co.	Arvonia	Arvonia

Crushed Stone.

The value of the production of crushed stone in Virginia in 1911 was $500,250, against $432,715 in 1912, an increase of $67,535. This material is used exclusively for road-making, railroad ballast, and concrete, and includes a wide range of rock-types, such as the crystalline siliceous rocks, limestone, etc.

The value of the crushed stone produced in Virginia from 1908 to 1912, inclusive, is given in the table below.

Value of annual production of Crushed Stone in Virginia, 1908-1912.

	Granite, Gneiss, etc.			Limestone			
Year	Road-making	Bal-last	Con-crete	Road-making	Bal-last	Con-crete	Total
1908	$ 21,670	$ 92,895	$ 81,745	$ 30,159	$ 45,541	$ 26,604	$298,614
1909	74,054	125,704	147,112	31,076	84,883	8,068	470,897
1910	40,691	111,811	156,894	20,056	108,129	36,849	474,430
1911	39,379	145,722	104,945	42,643	126,884	40,677	500,250
1912	54,540	49,480	115,427	56,500	115,576	41,192	432,715

Furnace Flux.

Limestone, used in smelting operations for flux, is quarried and shipped to the numerous blast furnaces in the State. The utilization of limestone as flux constitutes the largest consumption of the Virginia stone. Each of the principal limestone horizons in western Virginia supplies some stone as flux to the iron furnaces, but the Cambro-Ordovician and Lewistown (Helderbergian) limestones are the principal sources of stone for this purpose.

Of the total production ($369,872) of limstone in the State in 1911 only 39 per cent ($143,099) was sold as flux and utilized in the blast furnaces, and in 1912, 32 per cent was sold for the same purposes.

The value of the limestone sold as flux in 1912 was $130,916 against $143,099 in 1911, a slight decrease.

There are given in the table below the annual production and value of limestone as furnace flux in Virginia from 1908 to 1912, inclusive.

Production of Furnace Flux in Virginia, 1908-1912, in long tons.

Year	Quantity	Value
1908	290,847	$169,847
1909	388,746	213,444
1910	540,264	294,668
1911	281,968	143,099
1912	254,108	130,916

ABRASIVE MATERIALS.

Millstones (Buhrstones).

The millstone industry in Virginia is limited to the quarries in Brush Mountain, near Price's Fork, Montgomery County. A very marked increase in the production was shown for the years 1911 and 1912. The value of the production in 1911 was nearly three and a half times that of 1910, and that of 1912 was much larger than for 1911. The value of the millstone production in 1911 was $17,635 and in 1912, $25,866, an increase of $8,231. These figures represent the value of millstones of 12, 14, 15, 16, 20, 22, 24, 26, 30, 36, 42, and 48 inches in size, and of a small output of chasers (drag stones). Five operators contributed to the production for each of the years 1911 and 1912.

The value of millstones produced in Virginia from 1908 to 1912, inclusive, is given in the table below.

Value of Millstones produced in Virginia, 1908-1912, inclusive.

Year	Value
1908	$ 7,954
1909	12,348
1910	5,273
1911	17,635
1912	25,866

LIST OF ABRASIVE PRODUCERS.

OPERATOR	OFFICE	QUARRY
Cowan Millstone Co. (Formerly R. E. Snider)	Blacksburg	Brush Mountain, near Prices Fork
Linkous, F. C. & H. M.	Cambria	
Olinger, R. L., & Co.	Cambria	
Price, B. S., & Co.	Blacksburg	
Price, Zack	Cambria	

SILICA.

Under this heading are included three forms of silica which have rather wide distribution in the State. These are quartz, chert, and diatomaceous earth. There was no reported production of quartz and chert in 1911 and 1912, although preparations were in progress during 1912 for working several of the quartz deposits in 1913. The Vulcan Fire Brick Co., Baltimore, Md., with operations at Rollins Fork, King George County, was the only producer of diatomaceous earth in Virginia during the years 1911 and 1912, respectively, and, in order to avoid disclosing individual production, its output is included under "Other Products."

MICA.

Although Virginia has been an irregular producer of mica for many years, there was no production reported in 1912, and only one producer in 1911, namely, the Chestnut Mountain Mica Company, near Rocky Mount, Franklin County. Interest was revived in several of the Virginia mica mines in 1912, and active preparations were in progress for working in 1913.

LIST OF MICA OPERATORS.

OPERATOR	OFFICE	MINE
Chestnut Mountain Mica Co	Danville	Rocky Mount
Corson Mica Co	E. Stroudsburg, Pa.	Amelia
Fink, C. E. & J. B	Irwin	Irwin
Hanover Mica Co	Hewlett	Hewlett
Mecklenburg Mica & Mining Co	South Hill	South Hill
Otter Hill Mica Mines	Findlay, Ohio	Bedford City
Pinchbeck Mica Mines	Chula	Amelia C. H.
Reed, Mrs. E. P	Irwin	Irwin
Ridgeway Mica Co	Pittsburgh, Pa.	Ridgeway
Rutherford, A. H	Amelia C. H.	Amelia C. H.
Virginia Asbestos Co	Terre Haute, Ind.	Bedford City
Winston, Chas. P	Amelia C. H.	Amelia C. H.
Wooton & Fontaine	Axton	Martinsville

FELDSPAR.

The entire production of feldspar in the State during the years 1911 and 1912 was from a single operator, the Dominion State Mines Corporation, Prospect, hence the figures of production are combined with those of another subject, in order to avoid disclosing individual returns.

ASBESTOS.

No production of asbestos has been reported in Virginia since 1906, although the mineral has been noted in several of the Piedmont counties,

and has been mined in Bedford and Franklin. The mines have been inactive since 1906 and the mill at Bedford City for fiberizing the asbestos is closed.

TALC AND SOAPSTONE.

Virginia is vastly the most important producer of soapstone in the United States, exceeding both in quantity and value that of all other states combined. The production of talc and soapstone in Virginia during 1911 was 26,759 short tons, valued at $660,926, an increase of 851 short tons in quantity and $150,145 in value over that of 1910. The 1911 production was from 8 producers, operating in four counties, namely, Albemarle, Fairfax, Nelson, and Orange. In 1912 there were 8 producing quarries, operating in the counties of Albemarle, Fairfax, and Nelson. Only a small proportion of the total quantity of talc and soapstone quarried in Virginia is sold in the crude state. The production is classified in the following four groups: Rough or crude, sawed into slabs, manufactured articles, and ground.

The 1912 production was 32,665 short tons. Of this amount, 25,313 short tons valued at $576,473 were sold, a decrease of $84,453 in value from that of 1911. The decrease as indicated in the table below was shown both in the product sawed into slabs and that manufactured into articles.

The quantity and value of talc and soapstone produced in Virginia during 1911 and 1912, according to the condition in which it was marketed, are given in the subjoined table.

Production of Talc and Soapstone in Virginia during 1911 and 1912, according to varieties.

	1911		1912	
	Quantity	Value	Quantity	Value
Rough, Ground[a]	2,550	$ 16,450	3,240	$ 16,496
Sawed into slabs.............	3,384	69,631	2,527	47,596
Manufactured articles[b]	20,825	574,845	19,546	512,381
	26,759	$660,926	25,313	$576,473

[a]For paint, paper filling, complexion powders, lubricants, etc.

[b]Includes washtubs, laboratory or kitchen sinks, stove bricks, griddles, or other mill stock.

The yearly production of talc and soapstone in Virginia from 1908 to 1912, inclusive, is given in the table below.

Production of Talc and Soapstone in Virginia, 1908-1912, in short tons.

Year	Quantity	Value
1908	19,616	$458,252
1909	26,511	523,942
1910	25,908	510,781
1911	26,759	660.926
1912	25,313	576,473

LIST OF TALC AND SOAPSTONE PRODUCERS.

OPERATOR	OFFICE	QUARRY
Bull Run Talc & Soapstone Co	Clifton Station	Clifton Station
Climax Soapstone Co	Elmington, or New York, N. Y.	Elmington
Fairfax Soapstone Co	Wiehle	Wiehle
Horst, John B., & Son	Clifton Station	Clifton Station
Old Dominion Soapstone Corporation	Esmont	Damon
Phœnix Soapstone Co	New York, N. Y.	Arrington
Piedmont Soapstone Co	Asbestine	Asbestine
Utica Mining & Milling Co	Orange	Rhoadesville
Virginia Soapstone Co	Schuyler	Alberene and Schuyler
Virginia Talc & Soapstone Co	Verdiersville	Verdiersville

BARYTES.

The production of barytes in Virginia for each of the years 1911 and 1912 can not be published separately without disclosing the output of individual operations, hence the figures are combined with another subject.

LIST OF BARTYES PRODUCERS.

OPERATOR	OFFICE	MINE
Chism, Daniel C	Hurt	Pittsylvania County
Langhorne, R. H	Evington	Evington
Nulsen, Klein & Krausse Mfg. Co	St. Louis, Mo.	Toshes

GYPSUM.

Gypsum of excellent quality was mined in 1911 and 1912 by the Southern Gypsum Company at North Holston, three and a half miles northeast of Saltville, Smyth County, and by the United States Gypsum Company at Plasterco, Washington County. The crude gypsum is treated in the mills of the two companies on the respective properties, and the product put upon the market in the form of wall plaster and land plaster. The geology of these deposits is described by George W. Stose on pages 51-73 of this report.

The figures of production for each of the years 1911 and 1912 are combined with another subject, in order to avoid disclosing individual production, since there were only two producers.

LIST OF GYPSUM PRODUCERS.

OPERATOR	OFFICE	MINE
Southern Gypsum Co., Inc.	North Holston	North Holston
U. S. Gypsum Co. (a)	Chicago	Plasterco

aFormerly Buena Vista Plaster and Mining Co., Plasterco.

SALT.

Salt brines and rock salt occur in the Holston Valley of southwest Virginia in association with gypsum. More than 50 wells have been drilled, ranging in depth from 300 to 2,380 feet. These wells are confined to the immediate vicinity of Saltville, and are controlled by the Mathieson Alkali Works. Since 1903 the brines have been utilized exclusively for the manufacture of soda products, chiefly sodium carbonate and caustic soda.

The geology of these deposits is described by George W. Stose on pages 51-73 of this report.

MINERAL PAINTS.

The production of mineral paints in Virginia during 1912 was limited to the natural product ocher and came from one producer each in Bedford and Page counties. In 1912 the production included ocher and pigments (zinc oxide, ZnO) made directly from ores. The output in ocher was from Bedford, Page, and Pulaski counties, and that of zinc oxide (ZnO) from the Bertha Mineral Company at Austinville, Wythe County. The figures of production of mineral paints for 1911 and 1912 are combined with those of another subject.

LIST OF MINERAL PAINT PRODUCERS.

OPERATOR	OFFICE	MINE
Frazier Paint Co.	Detroit, Mich.	Bedford City
Hiwassee Chemical & Color Mines	Hiwassee	Hiwassee
Stigleman, W. T.	Snowville	Snowville
Virginia Ocher Corporation (a)	Irwin, Pa.	Stanleyton

aFormerly Page Ocher Corporation, Stanleyton.

MARL.

Greensand and shell marls are widely distributed over the Coastal Plain region of Virginia, but there was no reported production of either during

1911 and 1912. Shell marls in Isle of Wight County were dug and used by the Norfolk Portland Cement Corporation in the mix for the manufacture of Portland cement at their plant in Norfolk.

Fresh water calcareous marls of excellent grade and in quantity are found in several counties of the Valley region west of the Blue Ridge. Active preparations were in progress during 1912 in Bath and Rockingham counties to mine these marls for agricultural purposes.

PYRITE AND PYRRHOTITE.

Virginia has long held first position as a producer of pyrite among the pyrite-producing states in the United States. The production for the years 1911 and 1912 was from four operators as follows: Cabin Branch Mining Company's mine, near Dumfries, Prince William County; Arminius Chemical Company (Inc.) and Sulphur Mining and Railroad Company's mines, 1.5 and 4 miles, respectively, north of Mineral, Louisa County; and the Pulaski Mining Company's mine at Monarat, Carroll County. The ore mined by the Pulaski Mining Company at Monarat is chiefly pyrrhotite, which is utilized in their plant at Pulaski.

In addition to the producing properties in 1912 named above, one new property was being developed and plans for the reopening of several old ones were in progress. The Old Dominion Pyrite Mining Company began developing in 1912 a property located about 1 mile east of the Arminius mine and about 2 miles north of Mineral in Louisa County. Preparations were being made to reopen the Boyd Smith mine situated north of Mineral, between the mines of the Arminius Chemical Company and the Sulphur Mining and Railroad Company. The mine on Austin Run, near Stafford, Stafford County, developed by the Austin Run Mining Company was taken over by the Old Dominion Sulphur Company, for reopening and working.

The production of pyrite (concentrated and crude) in Virginia during 1912 amounted to 162,478 long tons, valued at $621,219, against 150,800 long tons, valued at $558,494 in 1911, an increase of 11,678 long tons in quantity and $62,725 in value. There was an increase in the average price per ton from $3.70 in 1911 to $3.82 in 1912. The average sulphur content in pyrite produced in Virginia during 1911 and 1912 was about 43 per cent.

There is given in the table below the production of pyrite in Virginia from 1908 to 1912, inclusive.

Production of Pyrite in Virginia, 1908-1912, inclusive.

Year	Quantity	Value	Average price per ton
1908	116,340	$435,522	$3.74
1909	114,176	423,283	3.71
1910	140,106	525,437	3.75
1911	150,800	558,494	3.70
1912	162,478	621,219	3.82

LIST OF PYRITE PRODUCERS.

OPERATOR	OFFICE	MINE
Arminius Chemical Co	Mineral	Mineral
Cabin Branch Mining Co	Baltimore, Md.	Dumfries
Pulaski Mining Co	New York, N. Y.	Monarat
Sulphur Mining & Railroad Co	Richmond	Mineral

ARSENIC.

The mines of the United States Arsenic Mines Company, located 14 miles southeast of Christiansburg, at Brinton, Floyd County, did not produce during 1911 and 1912. The ore is arsenopyrite, a sulph-arsenide of iron ($FeAsS$), and occurs in lenses in quartz-sericite schist.

RUTILE (Titanium).

Virginia is the only producer of rutile in the United States, and much of the product is shipped abroad. The American Rutile Company, operating at Roseland, Nelson County, was the only producer in 1911 and 1912. This company is mining and milling rutile in the hard rock syenite, and in 1912 added a magnetic separating machine to its equipment. The nelsonite occurrence of rutile in the same district is not now mined. There was no production of rutile in 1911 and 1912 from the recently exploited deposits of Goochland and Hanover counties in the central eastern portion of the Virginia Piedmont province.

The 1912 production was large and greatly in excess of that of any previous year.

MINERAL WATERS.

The production of mineral waters in Virginia during 1912 showed a marked increase in quantity and value over that of the previous year 1911. In 1912, the production of mineral waters was 2,762,319 gallons, valued at $349,255, as compared with 2,474,918 gallons, valued at $298,701 in 1911, an increase of 287,401 gallons in quantity, and $50,554 in value. These figures are exclusive of the quantity of water used in the manufacture

of soft drinks. The average price per gallon of the water sold in 1911 was 12 cents, and in 1912, 13 cents.

The following table gives the production and value of mineral waters in Virginia from 1908 to 1912, inclusive.

Production and value of Mineral Waters in Virginia, 1908 to 1912.

Year	Springs reporting sales	Quantity sold (Gallons)	Value
1908	46	2,009,614[a]	$207,115
1909	49	1,504,530[a]	203,455
1910	40	2,441,923[a]	301,523
1911	43	2,474,918[a]	298,701
1912	45	2,762,319[a]	349,255

a Amount used for soft drinks not included.

Of the 2,474,918 gallons of mineral waters sold in Virginia during 1911, valued at $298,701, $116,052 worth was sold for medicinal purposes and $182,649 worth for table or domestic use; and during 1912, of the $349,255 worth sold, $162,380 was for medicinal purposes, and $186,875 was for table or domestic use. The total number of springs reported as producing in 1911 was 43, and in 1912, 45. These were distributed among the following 24 counties: Alexandria, Amelia, Augusta, Bath, Botetourt, Chesterfield, Culpeper, Franklin, Henrico, Loudoun, Mecklenburg, Montgomery, Norfolk, Nottoway, Prince Edward, Princess Anne, Roanoke, Rockbridge, Rockingham, Surry, Sussex, Tazewell, Warwick, and Wythe.

Virginia occupied third place in 1911 and 1912 in the number of commercial springs in the United States, and also in the value of medicinal waters sold. As indicated above nearly one-half of the output is sold for medicinal use. Eleven springs reported resorts in 1912, accommodating 1,400 people, and at 6 the water is used for bathing. The returns show that about 91,000 gallons of water are used to make soft drinks, in addition to the sales.

Out of a total of 62 springs credited to Virginia, 43 reported sales in 1911, and 45 in 1912. The list of producing springs for the years 1911 and 1912 is as follows:

Alleghany Springs, Alleghany, Montgomery County.
Basic Spring, Basic City, Augusta County.
Bear Lithia Spring, near Elkton, Rockingham County.
Beaufont Spring, South Richmond, Chesterfield County.
Berry Hill Mineral Spring, Elkwood, Culpeper County.

Blue Ridge Springs, near Blue Ridge Springs, Botetourt County.
Bowman Spring, near Staunton, Augusta County.
Broad Rock Mineral Spring, near Richmond, Chesterfield County.
Brugh Spring, Nace, Botetourt County.
Buckhead Lithia Spring, Buckhead Springs, Chesterfield County.
Buffalo Lithia Spring, Buffalo Lithia Springs, Mecklenburg County.
Burnetts Spring, Hudson Mill, Culpeper County.
Campfield Lithia Well, Richmond, Chesterfield County.
Carper Lithia Springs, Radford, Montgomery County.
Como Lithia Spring, East Richmond, Henrico County.
Coppahaunk Mineral Springs, Waverly, Sussex County.
Crockett Arsenic Lithia Spring, Crockett Springs, Montgomery County.
Diamond Spring, Diamond Spring, Princess Anne County.
Erup Mineral Spring, near Glencarlyn, Alexandria County.
Farmville Lithia Springs, Farmville, Prince Edward County.
Fonticello Mineral Spring, near Manchester, Chesterfield County.
Harris Anti-Dyspeptic Spring, Burkeville, Nottoway County.
Healing Springs, Hot Springs, Bath County.
Iron-Lithia Springs, Tip Top, Tazewell County.
Jeffress Spring, Jeffress, Mecklenburg County.
Kayser Lithia Springs, Staunton, Augusta County.
Kiwassa Lithia Springs, near Manchester, Chesterfield County.
Landale Spring, near Ocean View, Norfolk County.
Lithia Magnesia Spring, Rocky Mount, Franklin County.
Magee Chlorinated Lithia Spring, Clarksville, Mecklenburg County.
Massanetta Spring, near Harrisonburg, Rockingham County.
Mecklenburg Mineral Spring, Chase City, Mecklenburg County.
Mico Well, Alexandria, Alexandria County.
Mulberry Island, Mulberry Island, Warwick County.
Nye Lithia Springs, Wytheville, Wythe County.
Otterburn Lithia Spring, near Amelia, Amelia County.
Pæonian Springs, Pæonian Springs, Loudoun County.
Pickett Spring, Worsham, Prince Edward County.
Roanoke Lithia Spring, Roanoke, Roanoke County.
Rockbridge Alum Springs, Rockbridge Alum Springs, Rockbridge County.
Rubino Healing Springs, Healing Springs, Bath County.
Seawright Spring, near Staunton, Augusta County.
Stribling Springs, Stribling Springs, Augusta County.
Tripho Mineral Spring, Claremont, Surry County.
Virginia Etna Spring, Vinton, Roanoke County.
Virginia Lithia (Lion Mineral), near Richmond.
Virginia Magnesian Alkaline Spring, near Staunton, Augusta County.
Wallawhatoola Springs, Millboro, Bath County.
Wyrick Mineral Spring, Crockett, Wythe County.

There are 49 springs listed above, three of which produced in 1911 that did not produce in 1912. These were Diamond Spring, Iron Lithia Spring, and Kiwassa Lithia Spring.

ZIRCONIFEROUS SANDSTONE NEAR ASHLAND, VIRGINIA[a]

BY THOMAS L. WATSON AND FRANK L. HESS.

INTRODUCTION.

In 1910, Mr. August Meyer, of Richmond, Virginia, submitted to one of the writers a specimen of rock obtained about three miles west of Ashland, which was thought to contain rutile. It was a fine-grained friable dark reddish-brown rock, in which grains of ilmenite or some similar black mineral were distinctly visible. The color of the other grains was apparently similar to that of the rutile found 10 to 15 miles farther southwest, in Hanover and Goochland counties, and under a hand lens no difference in appearance could be distinguished. As the rutile of these counties occurs with a very black ilmenite, it was thought that the specimen might possibly be a fine-grained mass of titanium minerals. Microscopic examination of a thin section, however, showed the rock to be a sandstone composed of very small grains of ilmenite and zircon (zirconium silicate, $ZrSiO_4$), together with a few grains of other minerals, chiefly quartz and silicates, cemented with limonite.

In June, 1911, the writers, in company with Mr. Meyer, visited the locality from which the latter obtained the original specimen, on the farm of Mr. F. B. Sheldon, 3 miles west of Ashland, Hanover County, and about 20 miles north of Richmond.

GENERAL GEOLOGY OF THE AREA.

The area of zirconiferous sandstone forms a part of the western edge of the Coastal Plain, near and along the overlap of the sediments upon the older crystalline rocks of the Piedmont Plateau (see map, fig. 1). Along this edge (the "fall-line") the surface is somewhat roughened from erosion, but to the east it becomes more gently rolling and is essentially flat and featureless. The area lies on the south side of South Anna River, but within its drainage basin and only a short distance southwest of its confluence with the North Anna to form Pamunkey River.

---

[a]Bull. 530-P, U. S. Geol. Survey, 1912; also Bull. Phil. Soc., University of Virginia, Scientific Section, 1912, vol. i, No. 11, pp. 267-292.

The sandstone outcrops along a low ridge having gently sloping sides and a general direction of N. 20° E. At the point where the sandstone seems to be most abundant and perhaps richest in zircon the ridge marks

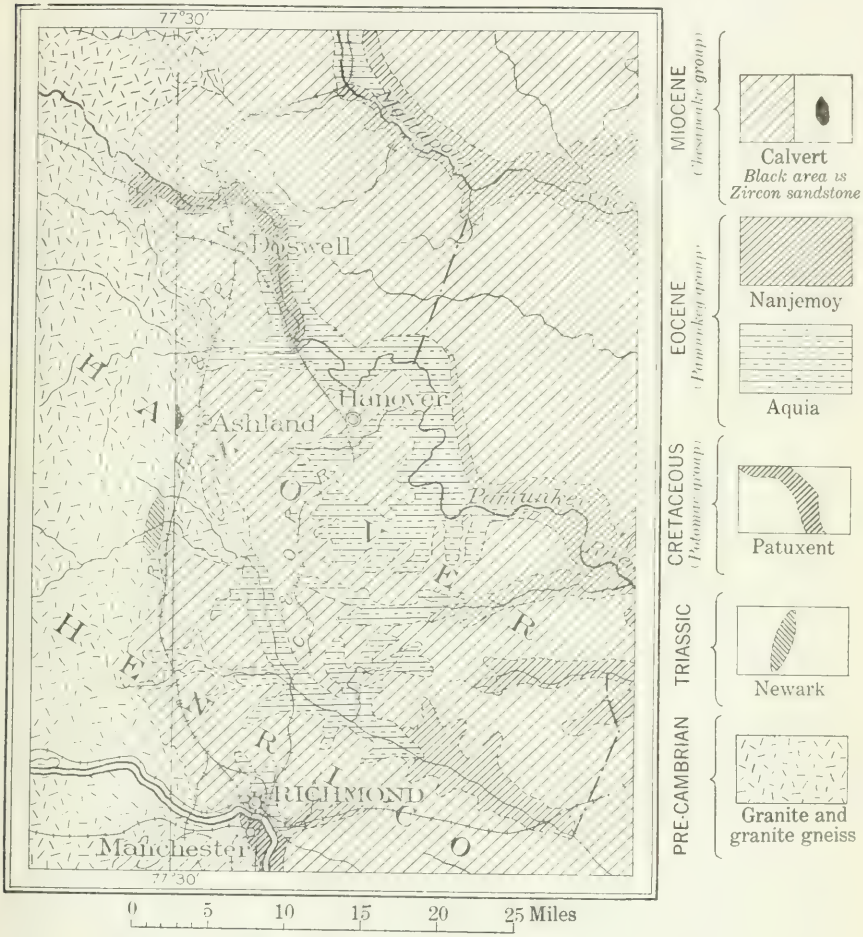

Fig. 2.—Geological map of a part of middle eastern Virginia, showing location of zirconiferous sandstone area west of Ashland, Hanover County. (Geological map of Virginia, Virginia Geological Survey, 1911.)

the western edge of the Calvert formation, the lowest formation of the Chesapeake group (Miocene). Within this area and for some distance north and as far south as a point 25 miles north of Petersburg the Calvert

formation transgresses the underlying older Coastal Plain sedimentary formations, and its western margin rests upon the crystalline rocks of the Piedmont Plateau.[a] The Calvert formation in Virginia is about 200 feet thick and consists chiefly of sands, clays, marls, and diatomaceous earth, fine-grained sands being predominant. Diatomaceous earth has not been identified in the Ashland area.

Extending westward from the foot of the west slope of the low ridge mentioned above are the crystalline rocks of the Piedmont Plateau, chiefly granites and gneisses, most of which are of pre-Cambrian age. The contact between the sedimentary formations of the Coastal Plain and the crystalline rocks of the Piedmont Plateau extends across the State in roughly a general north-south line and in position nearly coincides with the meridian 78° 30′.[b]

In the southern part of the State the Calvert formation is overlain by the St. Mary's formation (middle Miocene), and along the western edge the St. Mary's transgresses the Calvert and rests on the crystalline rocks of the Piedmont Plateau.

DISTRIBUTION AND OCCURRENCE OF THE SANDSTONE.

In the Ashland area the sandstone does not outcrop in a continuous bed. It was seen only in the form of irregular flat fragments lying loose upon the surface. The fragments are of the same reddish-brown to yellow color as the specimen submitted by Mr. Meyer. In size the fragments range from those as large as a man's fist to some measuring 2 feet long, 2 feet broad, and 6 inches thick. There is as much variation in texture as in size, and the rock accordingly ranges from a typical fine-grained sandstone to a typical moderately coarse conglomerate, with intermediate gradations. Much of it is very fine-grained, showing little visible quartz. Other pieces are of varying degrees of coarseness, some containing quartz and quartzite pebbles 2 inches in diameter. Some pieces show cross-bedded structure.

The largest number of the sandstone fragments were seen on a small mound 150 yards southwest of Mr. Sheldon's house, and scattered fragments can be found both to the north and the south for a distance of half a mile. On Mr. J. B. Davis's farm, which adjoins the Sheldon farm on the north, there are many pieces of the sandstone, though most of them are smaller. However, many of the pieces, especially those found farther north, are of lighter color and lower specific gravity than the fragments

[a] Virginia Geol. Survey. Bull. No. IV. 1912, p. 126 *et seq.*

[b] See the geological map of Virginia, Virginia Geological Survey, Charlottesville, 1911.

from the Sheldon farm, though one of the richest specimens collected was from the line between the Thomas Kies and John Boschen farms, half a mile north of the Sheldon farm. The specific gravity is of value in field examination, for specimens having low specific gravity show only a few grains of zircon, whereas those having high specific gravity carry a large percentage of the mineral.

It is probable that the hard lumps of sandstone represent the local cementation of a sandy bed which, in most places, is soft or but slightly consolidated, a characteristic of the Chesapeake group (Miocene). Partly or wholly indurated sands, yielding somewhat highly ferruginous crusts and beds of sandstone, are common in the formations of the Virginia Coastal Plain near its western margin. So far as the authors are aware these ferruginous sandstones have been generally regarded as composed chiefly of quartz grains cemented by iron oxide. At no point beyond the Ashland area, so far as known, have they been tested for zircon or other uncommon heavy minerals.

At the home of Mr. Benjamin Wright, three-eighths of a mile southwest of Mr. Sheldon's house, a highly zirconiferous and but slightly consolidated sand bed was cut in the lower part of a well 14 feet deep. This bed is probably the same one from which the indurated or hardened fragments of zirconiferous sandstone have come. Perfectly rounded water-worn quartz and quartzite pebbles, mostly quartz, up to 3 inches in diameter and usually white in color, were taken from this well at a depth of 14 feet. None of the zirconiferous material was found south of Mr. Wright's well, and decomposed granite is exposed in a road 200 yards southwest of his house.

A hundred yards northwest of Mr. Sheldon's house a bed of zirconiferous sand, similar to that cut in the Wright well, was exposed in a shallow prospect hole. The zirconiferous sand was 18 inches thick and was underlain by clay and covered by a few inches of soil.

From the appearance of the float and the sand cut in the prospect hole, the zirconiferous bed is thought to be probably not more than 2 to 3 feet thick. The data at hand indicate that it is probably a narrow lens three-eighths of a mile long and of unknown but probably of less width.

TESTS.

The zircon was separated from six lump samples weighing from 50 to 100 grains each as follows: The lumps were first treated with hydrochloric acid to dissolve the cement of limonite. In two specimens small lumps

resisted dissolution and were treated with aqua regia on a steam bath for two days, which resulted in dissolving the cement and disintegrating the sand grains. After washing by decantation the sand was digested with a mixture of sulphuric and hydrochloric acids to remove ilmenite and quartz and then washed. The specimens thus treated yielded zircon as follows:

Zircon obtained from sandstone near Ashland, Virginia.

Locality	Gross weight of sample	Zircon	
	Grams	*Grams*	*Per cent*
Specimen from low hill, F. B. Sheldon's farm..	50	14,955	29.9
Specimen from low hill, F. B. Sheldon's farm..	100	25,375	25.4
Specimen from low hill, F. B. Sheldon's farm..	52	6,280	12.1
Specimen from 100 yards northwest of F. B. Sheldon's house	100	15,890	15.9
Specimen from Wright's well..................	52	6,815	13.1
Specimen from top of hill on line between Thomas Kies' and John Boschen's land.....	100	27,230	27.2
Total		96,545	

Accessory heavy minerals in the form of impurities, such as cyanite, garnet, and staurolite, could not be separated from the zircon by the method used, and the results given in the table above are perhaps 2 to 3 per cent too high, though certainly not more. Owing to possible losses through the severe treatment during separation and to the loss of fine zircon in decanting, the tests are as likely to show less as more than the quantity present. The results are not, of course, to be regarded as exact, but the method of selecting random specimens from float rock would not warrant more accurate determinations.

It is not thought that the method used in separating the material introduced appreciable errors, as a blank test run on finely pulverized zircon by treating it with a mixture of sulphuric and hydrofluoric acids, showed at the end of three days no trace of zircon in solution.

The zircon crystals in the material are minute, averaging less than 0.5 mm. in diameter. Out of about 96 grams of zircon separated, a small quantity was caught on a sieve of 60 meshes to the linear inch; possibly 1 per cent would not pass through a sieve of 80-mesh; nearly 17 per cent (16.23 grams) passed through an 80-mesh and was caught on a 100-mesh sieve; 77 per cent (74.15 grams) passed through a 100-mesh sieve and was caught on a 150-mesh sieve; and more than 2 per cent (2.3 grams) passed

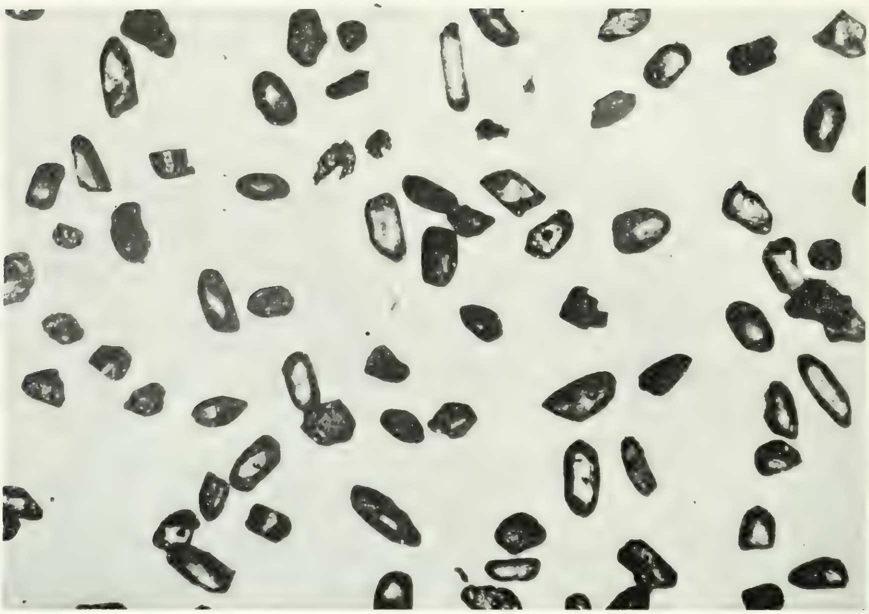

Fig. 1.—Microphotograph of zircon separated from sandstone obtained 3 miles west of Ashland, Virginia. Passed through a 150-mesh sieve. Rounding of the grains from wear is shown, but in many cases the original crystal outline can be seen. Magnified 97 diameters.

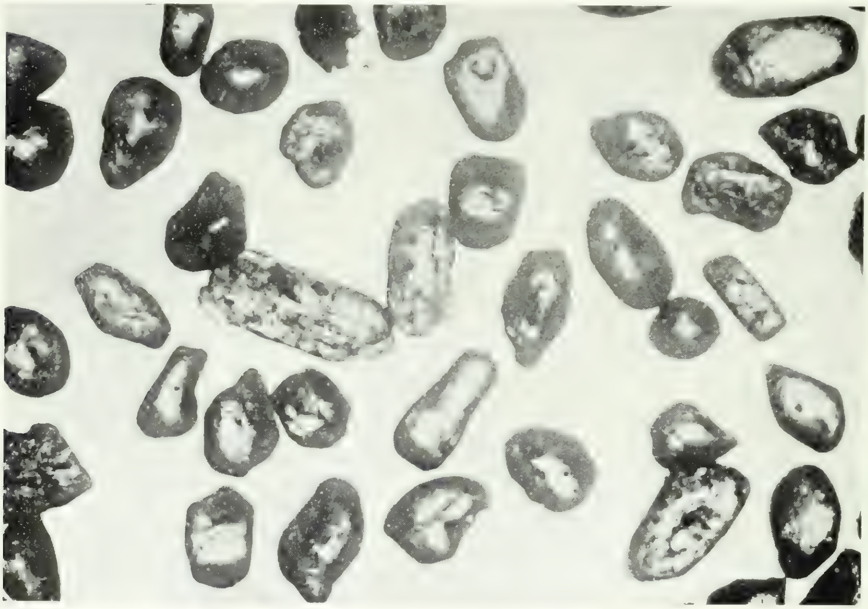

Fig. 2.—Microphotograph of zircon separated from sandstone obtained 3 miles west of Ashland, Virginia. Passed through an 80-mesh sieve and caught on a 100-mesh sieve. Rounding of the grains from wear is pronounced. Large prismatic grain to right of center is cyanite. Magnified 97 diameters.

MICROPHOTOGRAPHS OF ZIRCON SEPARATED FROM SANDSTONE.

through a 150-mesh sieve. Most of the accessory minerals (impurities) can be caught on an 80-mesh sieve.

CHARACTER OF THE SEPARATED ZIRCON CRYSTALS.

The zircon crystals, as separated above, are mostly of short, stout form, though they include a smaller number of elongated forms, possibly one and one-half times as long as thick. In mass they are pinkish or pinkish brown, but on heating to redness they become colorless. Under the microscope individual crystals are pink or yellow, but much the largest number are colorless. The crystals in most specimens are very much worn, but the crystals in the specimens from the prospect hole northwest of Mr. Sheldon's house show beautiful crystal form. Though nearly all of the zircon is undoubtedly worn, the wear in general may be in part apparent only, as small zircon crystals formed in place very commonly have outlines that do not show good faces or angles. The difference in the amount of wear of the particles which were caught on a 100-mesh sieve and of those which passed through a 150-mesh sieve is striking (see Pl. I, figs. 1 and 2). The greater mass of the larger crystals small as they are seems sufficient to cause much more fracturing from the force of impact when thrown around by waves and currents.

ASSOCIATED MINERALS.

Associated with the zircon are quartz and a variety of heavy minerals, including garnet (?), ilmenite, rutile, staurolite, cyanite, and an isotropic green mineral which has not been definitely determined but which may be pleonaste or hercynite. Occasional feldspar and pyrite were noted in several thin sections of the rock. As stated above, these are all cemented with limonite, possibly in part siliceous.

Ilmenite is the most abundant mineral in the rich pieces and its grains are of about the same size as those of zircon. The quartz and cyanite grains are generally several times as large. In places the fine-grained zircon and ilmenite surround quartz pebbles an inch long with the other dimensions somewhat smaller.

No magnetite was found in the material.

MICROSCOPICAL PETROGRAPHY.

The petrography of the rock is simple, but the general character of the minerals and their relations to one another and to the cement are more

definitely established by microscopic than by megascopic study. Considered as to mineral composition the ten thin sections of the rock studied may be divided into two groups, (1) zircon-ilmenite sandstone and (2) quartz sandstone. The rounding of the ilmenite and zircon grains is pronounced, but the quartz sand is remarkably angular[a] (see Pls. I and II). Both are cemented more or less firmly by oxide of iron, chiefly limonite and probably a less hydrous oxide of reddish color, possibly göthite or hematite.

Of the minerals present in the sandstone, zircon, ilmenite, and quartz are the three most abundant, and are described below in the order named. Occasional grains of an unstriated feldspar were noted in one or two of the quartz-rich sections, and red- to yellowish-brown rutile in partially rounded grains of variable size is sometimes present, always in association with ilmenite. Ferromagnesian minerals are entirely absent.

Zircon.

In the thin sections the zircon is mostly colorless, though occasional light yellow and pinkish crystals were observed, and is readily identified by its high refraction and double refraction. The grains usually show rounded outline and many of them are nearly spherical. They range from approximately equidimensional to elongate forms, and the angles or corners of those that exhibit squarish to rectangular cross-sections usually show more or less rounding (Pls. I and II). Crystal outline is frequently observed but as a rule it is modified by rounding from wear. Zircon grains separated from the rock and examined under the microscope usually show rounding from wear and rather dull luster (Pl. I, figs. 1 and 2). The most perfectly rounded grains are apt to exhibit the least luster. The zircon grains average from 0.2 to 0.3 mm. in diameter. Some of the larger elongated grains measure as much as 1.1 mm. in the direction of elongation. Some grains show cleavage and many indeterminable inclusions.

A fairly noticeable feature in many of the zircon grains is an apparent irregular, thin, cloudy and light-colored peripheral zone or border, which appears isotropic or but feebly double refracting. This border probably represents the pitted surface made by pounding against other fragments and possibly to some alteration from hydration.

---

[a]This is in accordance with the investigation of Mackie on the rounding of sand grains, who observed that grains of zircon were rounded more readily than those of quartz, due possibly to the greater density of the zircon. See Mackie, Wm., Trans. Edinburgh Geol. Soc., 1897, vol. vii, pp. 298-311.

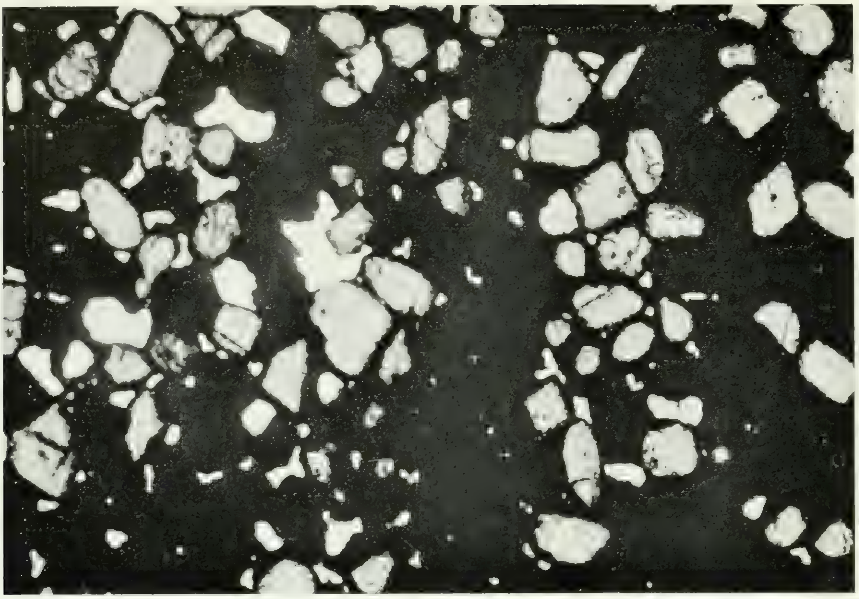

Fig. 1.—Microphotograph of a thin section of zirconiferous sandstone obtained 3 miles west of Ashland, Virginia. The grains of high relief showing rounding from wear are zircon; the smaller, angular, white grains are quartz; and the black groundmass is mostly ilmenite; the whole is cemented with limonite. Magnified 97 diameters.

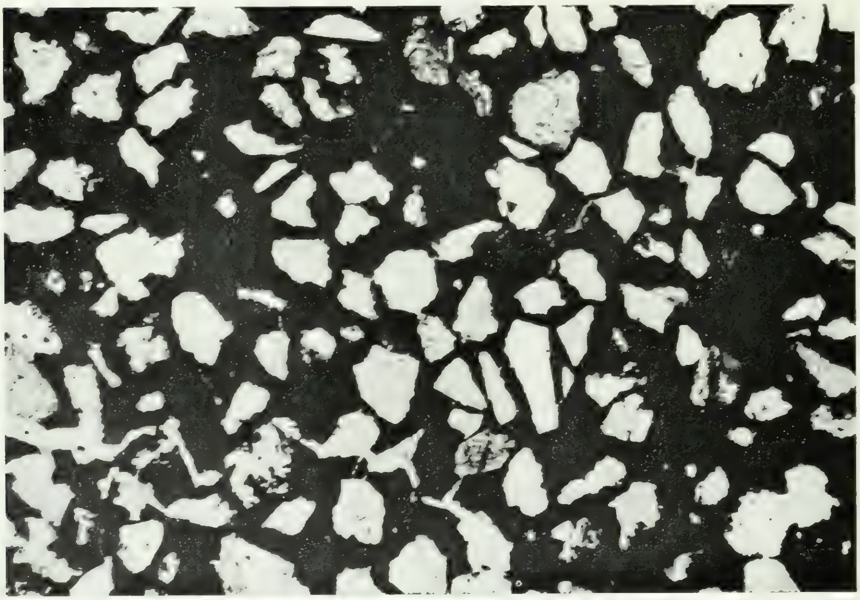

Fig. 2.—Microphotograph of a thin section of zircon-bearing sandstone obtained 3 miles west of Ashland, Virginia. The white, angular grains are mostly quartz with a few of feldspar; the scattered, roundish grains of high relief are zircon, and the black groundmass is mostly limonite, which forms the cement, with some grains of ilmenite. Magnified 97 diameters.

MICROPHOTOGRAPHS OF ZIRCONIFEROUS SANDSTONE.

Ilmenite.

Ilmenite is most abundant in the zircon-rich thin sections. It exceeds zircon in amount and is least in quantity in the quartz-rich sections, and almost absent from some. It is remarkably fresh, in grains of about the same size as the zircon grains, probably most of them a fraction larger, and of irregular though somewhat rounded outline.

Quartz.

Quartz is present in every thin section but varies greatly in amount, from occasional grains in the zircon-ilmenite-rich rock to the dominant and vastly the most abundant mineral in the quartz-rich rock. It is likewise subject to much variation in size and shape of grain. The grains generally range between 0.2 and 1 mm. in diameter, though smaller and larger ones were noted, and in contrast to zircon and ilmenite are mostly angular in outline. Well-rounded grains are not numerous.

The quartz grains are of granitic character and some contain abundant liquid and solid inclusions. Many of them show pronounced strain shadows as the result of dynamic forces to which the original rock from which they were derived was subjected. The quartz grains in the same thin section will usually average larger in size and more angular in outline than the zircon. The general character of the quartz grains is shown in Plate II, figure 2.

Cement.

In hand specimens the cement is a decided reddish-brown color. In thin sections it is opaque and generally brown in reflected light, and occasionally transparent and deep red in transmitted light. It is sharply differentiated from the mineral grains, which are remarkably fresh. No gradation from the iron-bearing mineral grains into the cement was observed, such as would be expected if the cement were derived by alteration of those iron-bearing minerals present in the rock.

GENESIS.

The zircon and ilmenite concentration evidently represents an old beach segregation along but within the western margin of the Miocene sediments of the Coastal Plain, of probably Calvert age, and is similar to the black-sand beaches of New Jersey, California, Oregon, New Zealand, New South Wales, and numerous other coasts, and to the gold-bearing garnet (so-called "ruby") sands of the beaches at Nome, Alaska (see fig. 3).

The zircon and other heavy minerals resistant to atmospheric agencies were derived by weathering processes from the crystalline rocks, chiefly

granites and gneisses, of the Piedmont Plateau, which extend westward from the Coastal Plain contact. These formed the country rock of the shore, and the zircon and associated minerals derived from them by weathering were accumulated by waters near the mouth of a small stream or behind a sheltered point, while the quartz sand was largely worn and carried away by the currents of the sea.

Zircon is an almost constant minor accessory mineral in the crystalline rocks, especially granites and gneisses, of this old shore and its extension westward, and in places it occurs in large masses. Thin sections of granites occurring immediately west of Ashland and at other places in the Piedmont Plateau of Virginia show the presence of zircon, chiefly as inclusions in the quartz and feldspar. Near Gouldin post-office, 10 to 15 miles southwest of the Ashland area, pieces of zircon 3 inches in diameter weathered out of pegmatite dikes have been noted on the surface. Massive zircon without crystal outline, measuring 4 by 6 inches, has been observed in the pegmatites of Amelia County, Virginia. Similar dikes occur in the gneiss-granite complex of the Piedmont Plateau, forming the old shore-line which extends entirely across Virginia from Maryland into North Carolina, roughly coinciding with the meridian of 77° 30″. The zircon in the sandstone was not derived, however, from the pegmatites in which it occurs in comparatively large masses, but from the granites and gneisses which carry it

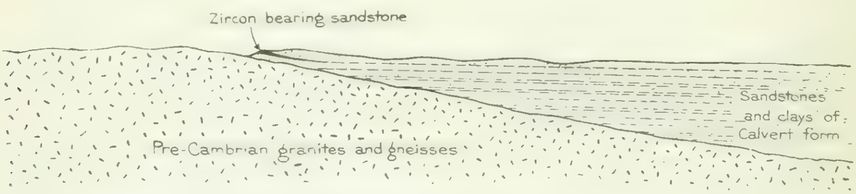

Fig. 3.—Generalized east west section across the fall-line near Ashland, Virginia, illustrating the occurrence of zircon-bearing sandstone.

in innumerable very small crystals. It seems probable that similar zircon-rich sandstones may accur at numerous points along this old shore-line. Many zircon-bearing deposits may be covered by later sediments and some may have been removed by erosion, but it is probable that others, which may be richer or poorer, will be discovered along the contact of the granite and gneiss of the Piedmont Plateau with the overlying sediments of the Coastal Plain.

It is probable that some magnetite was present with the ilmenite, and glauconite is abundant at places in the Calvert formation. The alteration of either of these minerals might produce limonite, which forms the cementing material. An occasional pyrite grain was observed in one or

two thin sections, and some hand specimens of the rock exhibit cavities which suggest the removal by decay of some previously existing mineral. From microscopic study of thin sections of the rock, it seems more probable, however, that the principal source of the cement was chemical precipitation from iron-bearing waters that percolated or filtered through the sand deposit.

ECONOMIC ASPECTS.

The uses of zircon enumerated below are largely suggested rather than actual and their practicability is mostly dependent on the cheapness of the zirconia and the quantity available. Böhm[a] states that large quantities of native zirconia (zirconium oxide) known as baddeleyite are found near Sao Paulo, Brazil, and that much has been shipped to Germany. This material, at the time he wrote, was being furnished at the following prices:

Composition and prices of baddeleyite.

Designation	ZrO_2	Fe_2O_3	SiO_2	Price per ton (2000 pounds)
	Per cent	*Per cent*	*Per cent*	
Zircon S-Erz	90-92	1.	8	$151
Zircon Z-Erz	90-92	7	1	155
Zircon-NS-Erz	98	0.8	1[a]	215

aRemainder H_2O.

The mineral quoted is in the form of oxide and for most purposes would be more desirable than zircon, which would have to be reduced to the oxide, and should sufficient native oxide be found to supply demands, competition would be difficult for zircon. For ferrozirconium or zirconium carbide the zircon could possibly be used without reduction to the oxide.

Should the demand for zircon and further testing of the Ashland deposit warrant exploitation, operations could be carried on with comparative ease. The rock crushes easily; the zircon and associated heavy minerals could be separated from the quartz by shaking tables, and the ilmenite could be picked out by a magnetic separator.

The demand for zircon is now small but, with the probable increased use of zirconia (ZrO_2), it will likely soon become greater.

Böhm[b] sums up the known and probable uses for zirconium substantially as follows:

---

aBöhm, C. R., Die Technische Verwendung der Zirconerde. Chem. Zeitung. Jahr 35, November 14, 1911, pp. 1261-1262.

bBöhm, C. R. Op. cit., pp. 1261-1262.

USES.

Zirconia (ZrO_2) has been used in place of lime and magnesia as the incandescing material in the oxy-hydrogen blowpipe, and a very small quantity of zirconium nitrate is used in making mantles for gas lights. Large quantities of zirconia were once used in the Nernst lamps, a form of incandescent electric lamp in which a small stick of zirconia and yttria is used as a glower, but its consumption is not now so large, owing to the competition of metallic filament lamps. Zirconium carbide has been used in making incandescent electric lamps, but this also has been superseded by metallic filament lamps. The property of incandescence possessed by zirconia has tempted arc-lamp manufacturers to use it in their electrodes, but thus far it has not been used successfully. Zirconia is an excellent insulator for both electricity and heat and when mixed with a conductor can be used for electric heaters. In the Heraeus iridium furnace the iridium may be protected by a glaze made from a zirconium salt in place of the thorium or yttrium salts now used. Zirconia makes an excellent and very refractory crucible, which is manufactured in many sizes by a German firm. Its refractoriness makes zirconia a suitable lining for electric furnaces, and Böhm suggests that it might be used for saggers, but for the ceramic trade it must be free from iron and cheap. He also suggests its use for the walls of furnaces, for the making of molds to withstand high temperatures, and for heat insulation. Owing to its inertness zirconia is suitable for chemical ware, and many forms are manufactured from it. The same property has led to its recommendation for certain medicinal uses, and in Röntgen ray therapy it is used in place of bismuth nitrate, which has sometimes given bad effects. Zirconia is a beautiful soft white powder which is well adapted for making paints and lacquers, as it is unaffected by gases, acids, or alkalies, and has good covering power. It makes a good opaque glass, but for this use the borate is better than the oxide. It is used for a polishing powder in place of tin oxide. Ferrozirconium is manufactured by one German firm for use in steel. Zirconium carbide is extremely hard and makes a valuable abrasive. Glass 7 mm. (¼-inch) thick is cut with it as readily as with a diamond.

Clear zircons of brownish, orange, or reddish color are cut for gems and are then known as hyacinths. There is no probability of stones sufficiently large for cutting being found at the Ashland locality, but they may be present in some of the pegmatites of the crystalline area.

GEOLOGY OF THE SALT AND GYPSUM DEPOSITS OF SOUTHWESTERN VIRGINIA[a]

BY GEORGE W. STOSE.

LOCATION.

Large deposits of salt and gypsum are known to occur along a belt of country 20 miles long running northeastward from the village of Plasterco, Va., and lying in Washington and Smyth counties. Much of this territory is in or near the valley of the North Fork of Holston River, and this

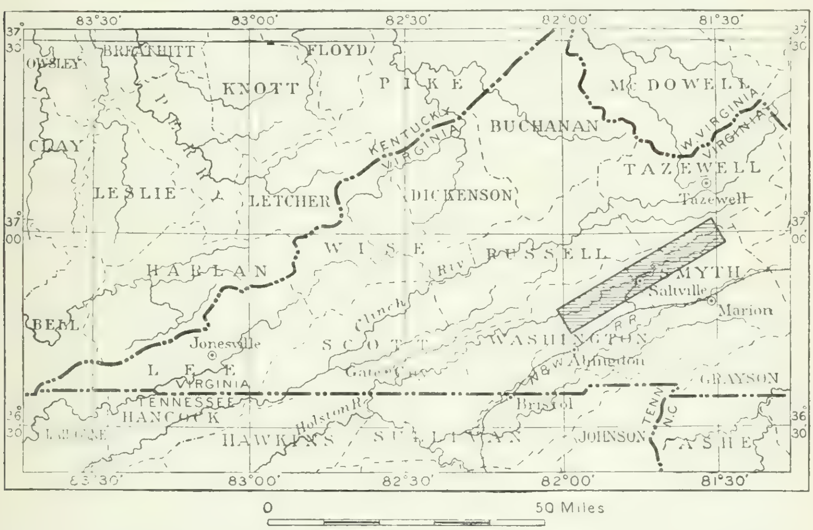

Fig. 4.—Index map of southwestern Virginia. The area described and mapped in this report is indicated by the shaded rectangle. Railroad connections for this area only are shown.

portion is made accessible to railroad transportation by the Saltville branch of the Norfolk & Western Railway, which joins the main line at Glade Spring. The location and relations of this area are shown in figure 4. Two gypsum plants and one salt or alkali works are now in operation in

---

[a]Republished with revision from Contributions to Economic Geology, 1911, U. S. Geological Survey Bull. 530, Part I.

this area. Numerous old gypsum workings and prospects indicate the extent of the deposits, some of which are at present not commercially workable because of lack of transportation facilities. The active mines, old workings, and prospects are shown on the geologic map in figure 5.

TOPOGRAPHY.

The area represented on the accompanying map (fig. 5) comprises a mountain ridge 1,000 feet high separating parallel valleys and rising above an adjacent deeply dissected plateau. The ridge, named Pine Mountain at the southwest and Brushy Mountain at the northeast, trends in a general N. 70° E. direction and its elevation ranges from 2,500 to 3,000 feet. It is cut nearly at right angles by several deep water gaps through which pass the waters from Clinch Mountain that drain into the North Fork of Holston River. This stream flows southwestward, in general hugging the foot of Pine Mountain, and its valley descends from an altitude of 2,000 feet at the northeast to 1,500 feet in the southwestern part of the area. The plateau to the southeast ranges from 2,000 to 2,500 feet in altitude and its surface is dissected into narrow transverse ridges and rounded hills.

GEOLOGY.

Stratigraphy.

The rocks in which the deposits occur are of Mississippian ("Lower Carboniferous") age. A generalized section of the Carboniferous rocks derived from several detailed sections in the vicinity of the mines is as follows:

Generalized section of Carboniferous rocks in the vicinity of Saltville, Va.

	Feet.
Newman limestone:	
Hard argillaceous limestone or calcareous shale, with a few beds of crystalline limestone	400+
Red calcareous sandstone and coarse crinoidal limestone, with some beds of argillaceous limestone	75
Light-blue to gray argillaceous, shaly limestone and calcareous shale, with a few thicker fossiliferous limestones	1,150
Largely thick even-grained blue fossiliferous limestone, with some beds of crystalline fossiliferous limestone	250
	1,875+

Maccrady formation:	Feet.
Earthy limestone and shale, dark gray, weathering lighter and crumbly, abundantly fossiliferous	225
Gray sandstone, mostly calcareous and crumbly, and shaly argillaceous or earthy limestone; fossiliferous at the top	120
Soft rocks, including shaly limestone and probably earthy sandstone and red shale, largely concealed	300
Upper part red shale and shaly sandstone, with some gray shaly sandstone; lower part soft light-buff shale, with thin black carbonaceous shale and coal seamlets, containing Mississippian plants	120
	765

Price sandstone:	Feet.
Hard irregular-bedded rusty-gray sandstone, with some heavier beds	95
Largely shaly sandstone, with a few harder beds	275
Massive gray to reddish-gray sandstone, thin bedded toward top, and fine conglomerate with scattered white quartz pebbles generally at base	50
	420

Devonian rocks:

Thin-bedded sandstone and sandy shale containing brachiopods of Chemung age.

Platy sandstone and slaty shale.

The Price sandstone is a hard ridge-making rock which forms the ridge known as Pine Mountain and Brushy Mountain. The southeastern face of this ridge is a dip slope of the hard rocks of this formation, which dip about 40° SE. The severed edges of the dipping strata are finely exposed in the gaps through the mountain and make picturesque ledges and cliffs. Less well exposed in the gaps and on the northwest slope of the ridge are the underlying shaly sandstones and shales which are sparingly fossiliferous and of Chemung age. The lithologic character of the Price sandstone, its general stratigraphic position, and the presence of coal seamlets near its top, indicate its equivalence to the Pocono, at the base of the Carboniferous system, and the invertebrate fossils obtained from it corroborate this opinion. In the adjacent region to the northeast the Price sandstone contains thick coal beds whose flora establishes its Mississippian age.

The Maccrady formation is composed of materials relatively so soft and easily disintegrated that it is deeply eroded and in general poorly exposed. It outcrops in the valley of the North Fork of the Holston but is largely covered by the terrace and flood-plain deposits of that stream.

The basal black shale and reddish sandy beds are not uncommonly exposed in the lower spurs of Pine Mountain, but the earthy limestones and shales of the formation are seen in few places. A few fossils have been found in some of the thin calcareous beds, and certain dark shales near the middle are in places highly fossiliferous. At the base are coal seamlets and underclays that carry plant remains. The invertebrates have been assigned by George H. Girty to the upper Mississippian, and he correlates the formation with the Moorefield shale of Arkansas. It also probably represents the lower part of the Mauch Chunk of Pennsylvania. In places plastic red and olive to bluish clays with gypsum deposits occur in the midst of the Maccrady formation. Their occurrence and relations are discussed under the heading "Origin of the Deposits," on pages 64-73. This formation has been called the Pulaski shale in geologic reports describing adjacent areas to the northeast, and this name would be used here were it not that Pulaski has a prior established usage for an Ordovician formation in New York. The new name Maccrady is here given to the formation, from the village of that name on the North Fork of Holston River, where the best section of the formation was measured.

The Newman limestone is calcareous throughout but contains shaly portions which weather readily to clay and soil. The limestone generally makes hills, which in most places assume rounded forms due to dissection by streams flowing across the trend of the beds into the larger longitudinal streams. The formation is highly fossiliferous and the fauna indicates its general equivalence with the Greenbrier limestone of West Virginia and Pennsylvania and the Batesville sandstone of Arkansas.

Pre-Carboniferous rocks are present in two tracts within the area presented on the map (fig. 5). Beneath the basal Carboniferous sandstone lie Devonian sediments, mostly shales and sandstones, about 2,700 feet thick, underlain in turn by Silurian sediments, also mostly shales and sandstones. These are not differentiated on the map, as they do not concern the problems here discussed. These rocks occupy the northwestern portion of the mapped area and form the slopes of Clinch Mountain, which is capped by the basal Silurian formation, the Clinch sandstone, of Medina age.

In the southeastern part of the area mapped are Cambrian strata, mostly hard gray to blue magnesian limestone and dolomite, which are also undifferentiated on the map. The oldest of these Cambrian rocks are adjacent to the Carboniferous, with successively younger beds to the southeast.

Structure.

The Cambrian rocks on the southeast are part of a great overthrust mass which rode on a flat fault plane over the Carboniferous strata on the northwest, as shown in the structure sections in figures 6 and 7. The Cambrian strata dip rather uniformly 30°-40° SE., successively older Cambrian strata appearing at the northwest. Massive gray dolomite and magnesian limestone of Cambrian age are adjacent to the fault throughout most of its course in the mapped area and probably form the competent strata that carried the thrust. There is no indication of an anticlinal axis in these lower limestones southwest of Saltville, where this formation has a narrow outcrop, but northeast of Saltville there is close folding in the broad belt of this formation adjacent to the fault, with all dips overturned to the southeast. A still lower Cambrian formation of red argillaceous shale and sandstone is exposed over part of this area. This folded portion of the Cambrian may represent the axis of an overturned anticline, the breaking and overthrusting of which initiated the faulting. This is no local or minor fault, however, for it has been traced throughout the southern Appalachians into the Rome fault, which has been demonstrated to have a horizontal displacement of at least 5 miles in the vicinity of Rome, Ga. A thrust fault of such magnitude and length must have a deep-seated origin and its plane may be a shear plane cutting diagonally across the strata, without folding except that produced by friction or drag.

The fault plane is exposed at several places in the area, dipping southeast, and its inclination varies from 20° to 60°. Figure 8 is a sketch of the faulted rocks in the cliff southwest of Maccrady. Next to the fault plane the dolomite of the overthrust mass is hardened and the bedding obliterated, and the vertical beds farther from the plane of movement are jointed parallel to the plane. The softer shaly limestones beneath are mashed and altered by circulating waters to clay adjacent to the fault.

Another section of the fault laid bare by old gypsum workings 2 miles east of Broad Ford shows the Cambrian dolomite resting on red and green clay containing gypsum, with 1 foot of black banded carbonized calcareous clay gouge directly beneath the fault plane, which dips 20°-40° SE. In places a dolomite breccia of large and small masses marks the fault contact. In the railroad cut at Plasterco the cemented breccia is freshly exposed and its components are seen to be largely dolomite, with minor fragments of chert, limestone, and shale.

Opposite Maccrady Gap a mass of Clinch sandstone of Silurian age and associated rocks of sufficient size to make a hill 250 feet high and nearly 1 mile long was caught up along the fault and is shown on the map (fig. 5) by the fault dividing west of North Holston.

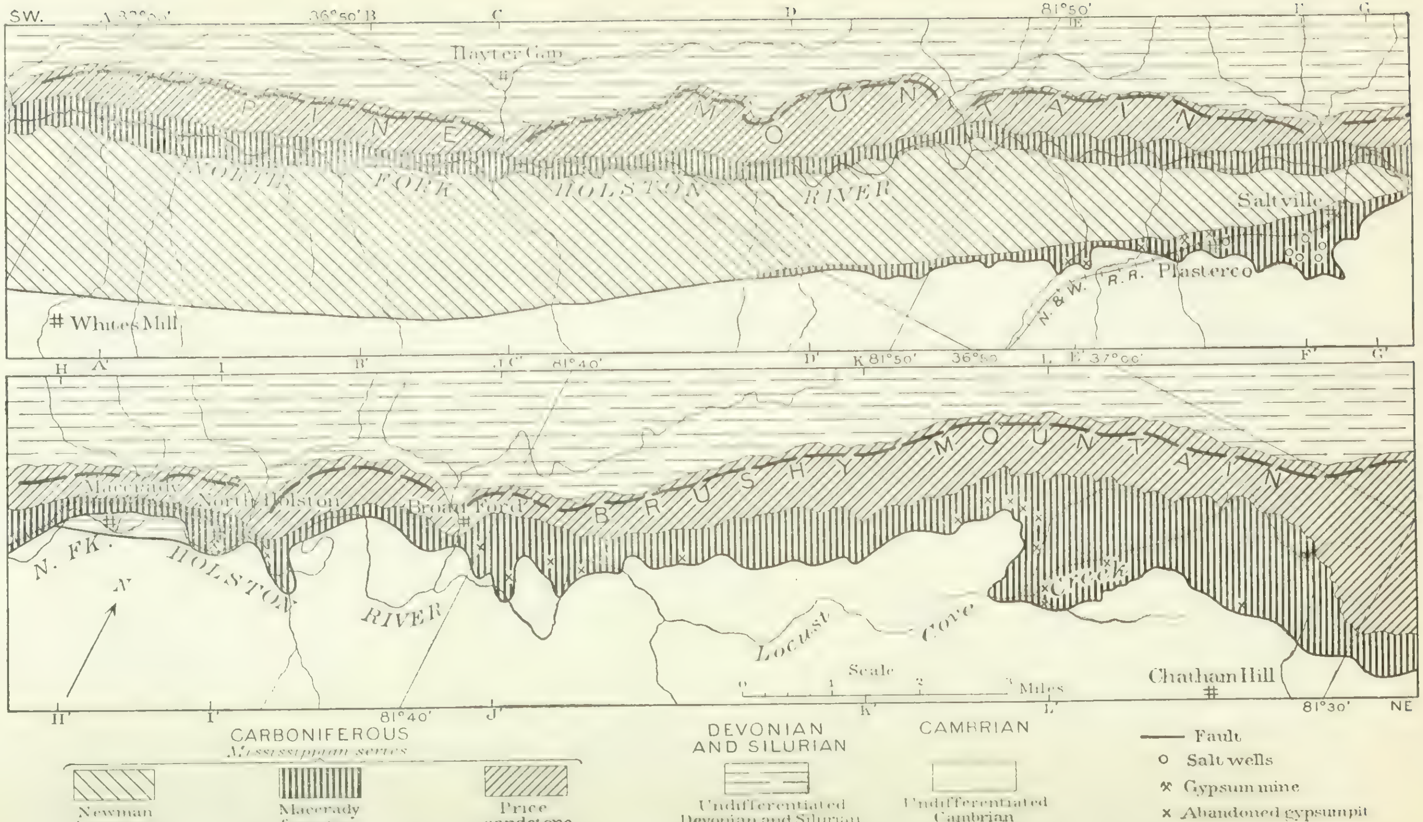

Fig. 5.—Geologic map of Holston Valley in the vicinity of Saltville, Va. The crest of Pine and Brushy mountains is represented by a heavy broken line. Letters on margins indicate lines of sections in figures 6 and 7.

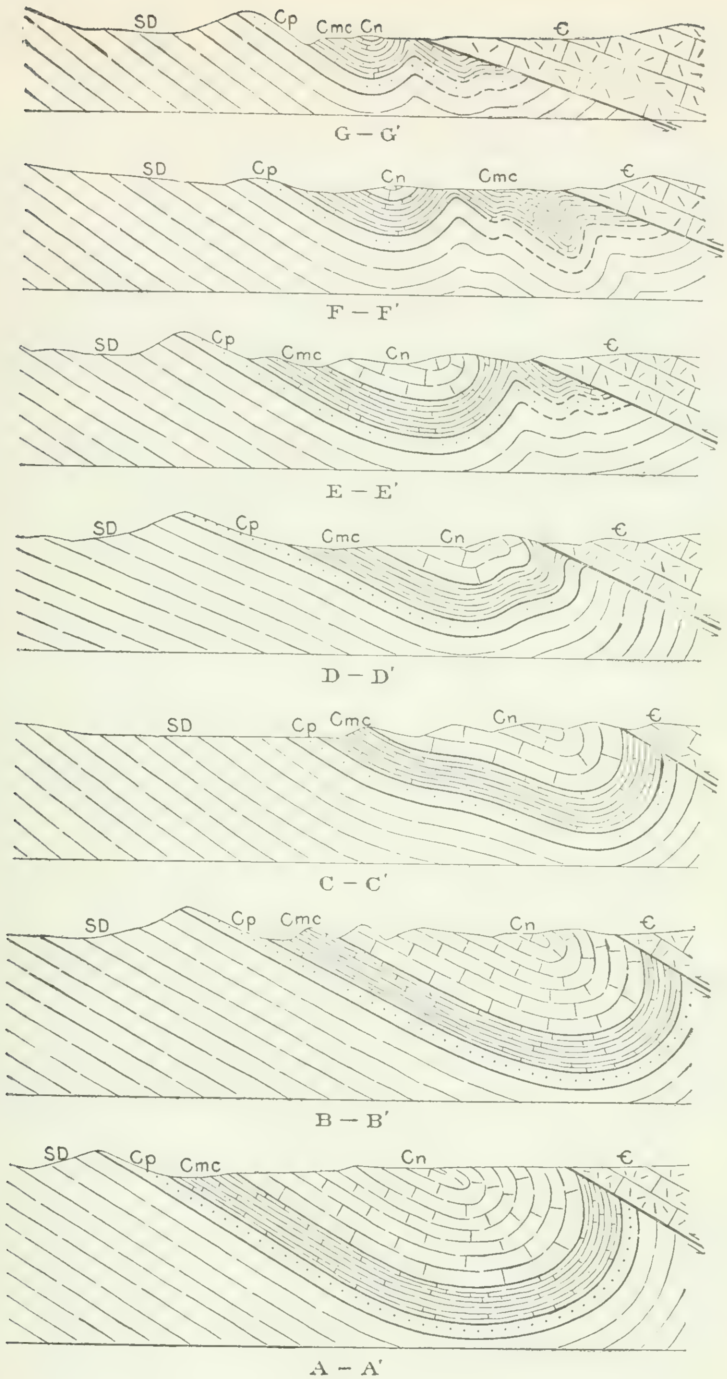

Fig. 6.—Structure sections across Holston Valley along lines indicated by letters on the margins of the geologic map (fig. 5). Cn, Newman limestone; Cmc, Maccrady formation; Cp, Price sandstone; SD, undifferentiated Devonian and Silurian rocks; Є, undifferentiated Cambrian rocks, mostly dolomite. Scale, double the scale of figure 5.

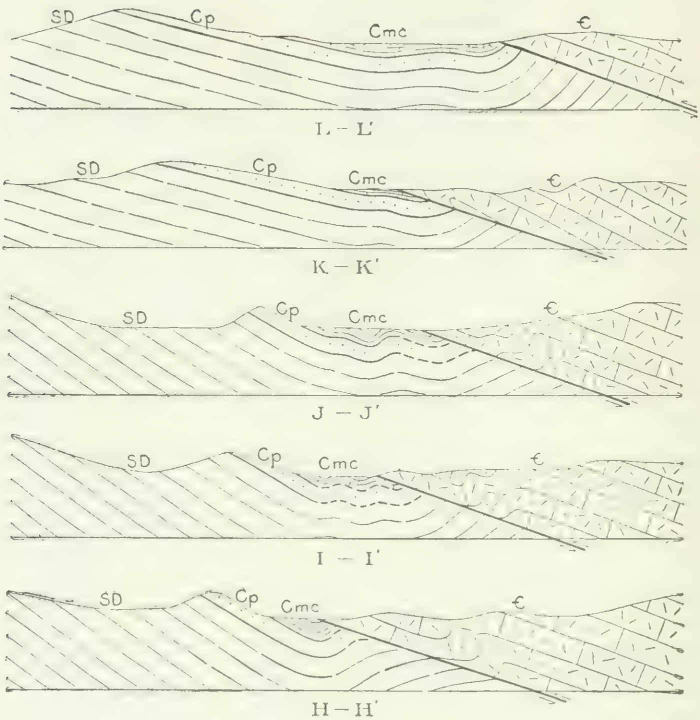

Fig. 7.—Structure sections across Holston Valley along lines indicated by letters on the margins of the geologic map (fig. 5). Cn, Newman limestone; Cmc, Maccrady formation; Cp, Price sandstone; SD, undifferentiated Devonian and Silurian rocks; Є, undifferentiated Cambrian rocks, mostly dolomite. Scale, double the scale of figure 5.

The outcrop of the fault plane is very crooked in the northeastern part of the area, owing to the facts that the plane is very flat in most places and is probably somewhat folded or wavy along the strike. Where the fault lies between the Cambrian dolomite and the shale of the Maccrady formation, it affords favorable channels for circulating underground water, from which springs issue at many places, and large solution channels are formed that may have aided in breaking down and removing the overlying dolomite at their outlets along the fault and may have assisted the formation of deep reëntrants in the trace of the plane. These reëntrants are invariably underlain by soft clays of the Maccrady formation, which form low flats generally without rock exposures. The reëntrant at Saltville is one of the largest, and is entirely barren of rock exposures. Another reëntrant is at Broad Ford, where there are only a few outcrops of the lower harder beds in the Maccrady. Northwest of Chatham Hill is a still larger reëntrant, due to the flattening of the general structure and a corresponding wider exposure of the softer rocks after being stripped of the overthrust Cambrian dolomite. These reëntrant areas are the chief places where salt and gypsum deposits have been found and are of especial interest in the study of the distribution and origin of these products.

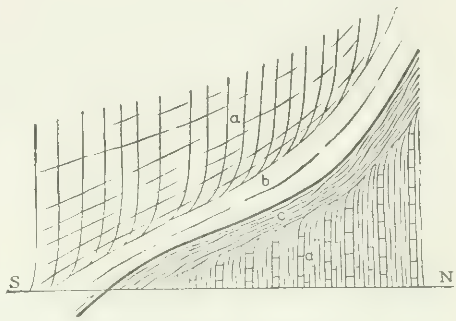

Fig. 8.—Section of the faulted rocks in the cliff southwest of Maccrady, Va. a, Massive Cambrian dolomite, bedding vertical but indistinct, jointing parallel to fault; b, zone of altered dolomite, bedding entirely obliterated; c, zone of altered and crushed argillaceous material, banded parallel to the fault; d, earthy limestone and calcareous shale (Carboniferous).

The rocks northwest of the fault, except those immediately adjacent to it, lie in a monocline, dipping 25°-40° SE., which culminates in Clinch Mountain, northwest of the area mapped. The soft Carboniferous rocks near the fault are bent into an overturned syncline. The sections in figures 6 and 7 illustrate the progressive rise in this syncline from southwest to northeast. As the Newman limestone rises northward in the shallowing syncline, erosion has removed its upper portion and its remnant gradually diminishes in thickness from 3,300 feet in the most southern section until northeast of Saltville it is entirely absent. The

soft underlying Maccrady formation does not extend all the way along the southeast side of the syncline, but is faulted out in the southwestern part of the area. Where present on the southeast side it is vertical or overturned.

No outcrops are visible in the broad flat at Saltville, but the absence of hard outcropping strata and the record of only soft rocks of Maccrady type in the deep wells at this place indicate that the syncline is followed on the east by an anticline whose east limb carries the Price sandstone below the points reached by the drill but apparently not deep enough to bring the Newman limestone down to the surface, so on the sections the rocks are shown to be undulating in the portions under cover of the overthrust fault.

Northeast of Saltville the beds of the Maccrady formation are so poorly exposed that their attitude is not generally shown. At the cliff west of Maccrady the last clear exposure of the syncline is preserved in the ledges of shale and sandstone. Just east of North Holston a small anticlinal roll of thin limestone in the Maccrady is an indication of the undulations probably existing throughout this band of soft rocks. East of Broad Ford a similar gentle fold is exposed in the small stream gully crossing the lowland.

Farther northeast the structure flattens more and more, and in the reëntrant northwest of Chatham Hill a thin limestone in the Maccrady formation indicates a very gentle syncline, followed on the southeast by a gentle anticline and another syncline, which is sharply turned up at the fault. The gentle syncline is also shown in the southward swing of the Price sandstone outcrops forming Brushy Mountain at the northeast end of the area mapped.

From the overturned syncline of Newman limestone at the southwest it might at first be concluded that this was a syncline associated with an overturned anticline on the southeast, which broke and was thrust over upon the syncline. However, it is concluded from a wider study of the structure that the fault did not originate in a broken fold but is of deeper-seated origin, being manifest by a shear plane cutting diagonally across the strata and folding and crumpling those at the overridden contact by reason of friction and drag.

SALT AND GYPSUM INDUSTRIES.

Salt.

Salt seepages were known to exist in the vicinity of Saltville in pioneer days, for this swampy flat was one of the salt licks frequented by wild animals and was sought by hunters and trappers and before them by the Indians. The early settlers dug shallow wells and extracted the salt from the brine that flowed from the springs. As early as 1836 two wells were reported in operation. During the Civil War the wells at Saltville were the main source of salt for the Confederacy. A brief history of the salt and gypsum industries of this region is given by T. L. Watson, Mineral Resources of Virginia.[a]

Present development.—The salt industry is now conducted by the Mathieson Alkali Works, with offices at Saltville. The Saltville Valley and surrounding country are owned and controlled by the company.

Since 1895, when the Mathieson Co. came into control of the property, the brine has not been evaporated into salt, but is converted by a modified and improved ammonia-soda process into soda products, chiefly sodium bicarbonate, or baking soda, which is the basis of all baking powders and is used also to some extent in making soda water. A large part of the production is in the form of soda ash, used extensively in the manufacture of glass, pottery, etc. Sal soda is also made for this purpose. Caustic soda, put up in large hermetically sealed cans, is prepared for medicinal and other purposes.

Over 50 wells have been drilled in the vicinity of Saltville, about 25 of which are at present in operation. They range in depth from a few hundred feet to 2,280 feet, the average being about 1,000 feet. The shallower wells are on the northwest side of the flat and the deeper ones on the southeast side, near the fault. The former are dry wells and have to be flushed with water through the outer casing. The wells on the southeast side are wet and the brine flows in as fast as it is pumped out. In the wet wells the rocks become honeycombed and cave in, in some wells bending the pipe so as to cripple or entirely disable the well. The brine is raised by ordinary deep pumps each operated by a walking beam driven by an electric motor housed in a small shack at the well, and the brine is piped to an open reservoir in the town. From the reservoir it is piped to the company's plant covering several acres on the east bank

[a]Watson, T. L., Mineral Resources of Virginia, Jamestown Exposition Com., 1907, pp. 211-213.

of the North Fork of Holston River, about a mile distant, where it is converted into baking soda and the other sodium products.

For the conversion of salt to these compounds large quantities of pure calcium carbonate are used, and an aerial bucket tram carries crushed limestone from the company's quarry 3 miles southeast across the limestone hills. As the limestone must be free from magnesium and other impurities, satisfactory rock is difficult to obtain in quantity. Part of the present supply comes from quarries at Marion, Va., about 25 miles distant by rail on the main line of the Norfolk & Western Railway. About 600 tons is used daily.

Gypsum.

Gypsum has been used for fertilizer for many years, and as early as 1835 the great possibilities of this deposit as a source of supply for the agricultural lands of Virginia were recognized. Over a decade ago gypsum was converted to plaster of Paris by roasting on only a small scale, as the product did not then have wide usage, but the adoption of this kind of plaster for walls in buildings, especially as a finishing coating, because of its superior hardness and whiteness, has made its production a large and profitable industry. When mixed with cement it acts as a retarder, greatly increasing the value of that product, and for gypsum to be used in this way there is now a large demand. As land plaster or fertilizer the gypsum is simply ground and not roasted. It has proved very beneficial to certain soils and for certain crops, being highly recommended for peanut cultivation.

Present development.—Two gypsum companies are operating in the area at the present time. The United States Gypsum Co., with offices in Chicago, leased the Robertson tract, adjoining the Mathieson Alkali Co.'s property on the southwest, from the Buena Vista Plaster Co. and has been operating for the last few years. This plant is located in a narrow extension of the broad flat at Saltville, separated from it by a low divide. Two shafts furnish access to the workings, which are reported to be about 100 feet below the surface, each set of workings seeming to be in a distinct body of gypsum. A third abandoned shaft leads to another mass of the deposit, and as other new bodies are located by drilling over the bottom land additional shafts will be sunk. Large deposits of gypsum on the eastern edge of the tract directly adjoining the Mathieson property were previously worked out by the owners.

As just mentioned, the gypsum in this mine seems to be in detached masses of great size and not in continuous beds, as might be expected.

This will be referred to again later under the heading "Origin of the Deposits." The gypsum is mostly a white to gray granocrystalline rock inclosed in clay, the gray variety streaked with fine dark argillaceous material. Numerous small anhydrite crystals are scattered through some of the gypsum from the old southernmost shaft, and these appear more prominently on weathered specimens. The gypsum is brought to the surface by elevators and conveyed by tram cars to the company's mill, where it is roasted and pulverized. The molding of plaster bricks, tiles, and hollow blocks in the company's shop is a new branch of the industry in this region.

The Southern Gypsum Co.'s plant and office are at North Holston, reached by the company's branch railroad from Saltville. The mine is on the old Pierson plaster-bank farm, in one of the embayments of lowland adjoining the North Fork of Holston River which is underlain by the soft shales of the Maccrady formation. The shaft in the lowland is connected by an aerial bucket tram with the main roasting and grinding plant at the railroad on the hillside. A large part of the crude product is ground for fertilizer at the lower mill near the shaft, much of the gypsiferous clay being of the right mixture to be used in this way for land plaster, effecting a great saving in the expense of mining. For wall and finishing plaster and cement retarder only the purer lump gypsum is employed.

The bulk of the gypsum here is much like that at the United States Co.'s plant, granular and crystalline. Some large sheets of pure selenite are encountered, and small veinlets of satin spar are common in the clay. Large masses of black argillaceous material called "black rock" occur in the midst of the gypsum, and apparent bedding of the gypsum is indicated by banding of black grains of the same material. The gypsum is reported to occur in beds of considerable thickness and extent and not in isolated masses, as at the United States Co.'s mine. The deposits have been tested by bore holes over all the river bottom of the embayment. The beds vary greatly in thickness, however, being somewhat lenticular in shape. The gypsum formerly outcropped at the river, where it was mined in open cuts in the early days for fertilizer. It is now mined from the shaft in the bottom land in all directions at a maximum depth of about 100 feet.

Deposits not at present utilized.—Old partly filled pits where gypsum, or "plaster," as it is commonly called, was mined from the surface in earlier days are visible all along this belt from a point a mile west of Plasterco to the vicinity of Chatham Hill. Large quantities of good gypsum still remain in these old workings. Near Plasterco large pits,

abandoned shafts, and caved-in ground abound, marking the places where the Buena Vista Co. and the Robertsons formerly operated extensively and removed much of the available gypsum that was close to the surface. Smaller openings were made in the embayment about 1 mile to the southwest, but the deposits there have been only slightly explored. They are all owned by the old Buena Vista Co. and are leased to the United States Gypsum Co. In the Saltville Valley thick deposits of gypsum are reported in all the wells drilled for salt, and some beds at the surface were formerly mined for the manufacture of a kind of cement. They are owned by the Mathieson Alkali Co. and are not now being worked.

At North Holston and in the embayment just east of it several old gypsum pits formerly worked on the Pierson and Miller farms are nearly obliterated. Several old pits are to be seen also near Broad Ford, some to the west but most of them in the broad embayment to the east. One is still open in the river bank on the Taylor farm, about a mile east of Broad Ford, where the gypsiferous shales have been dug out from beneath the overthrust Cambrian dolomite. Another pit on the Taylor farm is among the low hills to the northeast, beyond the point where the North Fork of Holston River leaves the belt of the Maccrady formation. A shaft on the adjacent Barnes place opened a large deposit by drifts but is now abandoned and filled with water.

Northeast of the Taylor farm conditions continue to appear favorable for the occurrence of gypsum, except that the exposed area of the Maccrady formation is narrow, but gypsum is not known to have been reported in the next 3 miles. Beyond, however, on the Buchanan property, important deposits occur and were mined on a large scale and crushed in the company's mill on the property. The smaller holes have fallen in and been filled up, but some of the larger ones are full of water and are reported to be very deep. Pits are scattered over the broad embayment in the Maccrady formation not only in the Locust Cove Creek bottom but also on the low divide and small valley to the west. Several pits were also located north of Chatham Hill, and the crude gypsum was crushed in a water-power mill on the river at Chatham Hill.

ORIGIN OF THE DEPOSITS.

Former Views.

In his early description of these deposits W. B. Rogers correctly identifies the beds inclosing them as "Lower Carboniferous" and states further that they are at the fault contact between these beds and older

limestones. As to their origin he adopts the explanation that oxidizing iron pyrites in the shales produced sulphuric acid, which, acting on limestone, converted it into calcium sulphate. He says:[a]

In speculating upon the origin of the gypsum of this region, the readiest explanation that suggests itself is that which ascribes its production to similar causes with those which gave birth to the gypsum of the Tertiary strata of lower Virginia. It has been incidentally remarked above that pyritous slate occurs in fragments mingled with the gypsum and clay of the salt wells and other places. Supposing the valley to have once been filled with the débris of this slate and of the neighboring limestones, we would have all the materials brought together which are necessary for the production of the gypsum, while the slate after decomposition would become the clayey matrix in which the crystals would collect. This view is rendered more probable from the occurrence, even in the midst of the solid masses of plaster, of fragments of the siliceous rock which skirts the valley on the south. It is at least certain that the gypsum has not been deposited here, as in some other parts of the world, from the waters of thermal springs holding it in solution, since in that case it would be found disposed in layers as travertine and not in the irregular and scattered condition which has been described.

J. J. Stevenson,[b] in 1885, after describing the mining development, occurrence, and distribution of the gypsum and salt, arrives at somewhat similar conclusions, as follows:

1. The gypsum deposits are not beds of Carboniferous or Cambro-Silurian limestones changed into gypsum.
2. These deposits occupy deep basins, which have been eroded in Lower Carboniferous shale or limestone or in the hard, slightly calcareous sandstones of the Knox group. In at least two localities branches protrude from the main body into drains or ravines, so that the horizontal plan resembles somewhat the splash made by throwing soft mud against a wall.
3. The character of the deposit is wholly independent of the rocks on which it rests.
4. The gypsum occurs in irregular masses, incased in red marly clay, which penetrates the gypsum to a variable distance; there is less of this clay in the eastern basins than at Saltville.
5. At a variable depth salt occurs with the gypsum, and this salt contains very little of iodides or bromides.
6. Blue clay overlies the gypsum at all localities yet examined.
7. No fossils of any sort have been found thus far in the gypsum, its incasing red clay, or in the overlying blue clay; but just west from Saltville a conglomerate cemented by gypsum occurs, in which remains of Mastodon have been found; this overlies the blue clay and incloses many fragments of both blue and red clay.
8. These gypsiferous deposits occur in the vicinity of the Saltville fault.

. . . .

But the amount of the erosion and the general relation of the gypsum to the blue clay, with the relation of the latter to the Quaternary conglomerate, suggest that the gypsum is not older than the Tertiary; until some fossils have been discovered, however, the question of age must be regarded as undetermined.

. . . .

Capellini ascribes the formation of this gypsum [at Castellina Marittima] to the action of sulphur springs on calcium carbonate held in solution; so that the

---

[a]Rogers, W. B., A reprint of annual reports . . . on the geology of the Virginias, 1884, pp. 141-142.

[b]Proc. Am. Philos. Soc., vol. xxii, 1885, pp. 157-160.

carbonate was changed into sulphate and deposited as such in the littoral lakes of the middle Miocene. . . . The origin of the Holston gypsum is to be accounted for in some similar way. Several deep basins were occupied by lakes; that of the Saltville basin received not a little calcareous matter from the Lower Carboniferous beds forming its northerly shore, and some doubtless was received from the wash of the Knox beds on the southerly shore; in the basins farther east the calcareous matter derived from the wash should be far inferior to argillaceous matter. But the composition of the gypsum shows less of the red clay at Buchanan's than at Saltville. The principal source of the calcareous matter must be looked for not in the wash from the shores but in springs. That calcareous springs can produce deposits as extensive as those of this region is sufficiently shown by the extensive deposits around many of the springs at the far West. The calcium carbonate in solution would be converted into calcium sulphate by the sulphurous springs also issuing from the fault, and the gypsum would be deposited as such.

The red marly clays were derived from the wash and are more abundant at Saltville, where the soft red shales at the top of the Lower Carboniferous are fully exposed on the northerly side of the basin.

E. C. Eckel,[a] in 1902, concluded that the deposits were interbedded as original sediments in the "Lower Carboniferous":

Though the salt and gypsum deposits have been long known and worked and have been examined by many geologists, a wide range of opinion exists as to their age and origin, as will be seen on comparing the literature of the subject. It is sufficient in this place to note that, as to age, the deposits have been variously referred to the Silurian, Carboniferous, Triassic, Tertiary, and Pleistocene, while different authorities have considered them as originating from deposition from sea water, from deposition from lakes, by the decomposition of pyrite and resulting action on fragments of limestone, or by the action of sulphur springs on unweathered limestone.

The work of the last field season would seem to prove that both the salt and gypsum deposits originated from deposition, through the evaporation of sea water in a partly or entirely inclosed basin, and that they are of Lower Carboniferous age, being immediately overlain by the massive beds of the Greenbrier limestone and underlain by Lower Carboniferous sandstones.

Observed Relations.

The most striking fact in connection with the gypsum and salt deposits of this district is that they have been found in quantity only in the shales of the Maccrady formation along the Saltville fault. These shales also outcrop along the North Fork of the Holston southwest of Saltville, on the west side of the syncline, but so far as known neither gypsum nor salt has been observed in this area of the formation. Stevenson reported gypsum on both sides of the fault on the Miller and Buchanan tracts northeast of Saltville, but these observations seem to be in error in that the fault was not accurately mapped, which is not strange, for the altered Carboniferous limestone very closely resembles the Cambrian dolomite, and some of the red shales of the Cambrian closely resemble those of the Carboniferous.

---

[a]Bull. U. S. Geol. Survey No. 213, 1903, p. 406.

An effort has been made to obtain a carefully measured section of the Maccrady formation to determine the position of the gypsum and salt-bearing beds, but with scant success. In the broad flats where the gypsum occurs there are generally no outcrops except red clay and gypsum, and consequently there is little hope of solving the relation southwest of Saltville. Not even the base of the Maccrady, which is the most definite key horizon, is exposed there.

Northeast of Saltville there are a few good exposures, but generally where the gypsum occurs the inclosing rocks are soft clays and are hidden. The river cliff southwest of Maccrady is the best exposed section of these beds in the area, and the following details were measured there:

Partial section of Maccrady formation west of Maccrady, Va.

	Thickness
	Feet.
Dark crumbly fossiliferous shale and earthy gray limestones	50±
Alternate thick earthy limestone, calcareous shale, and thin crystalline fossiliferous limestones	60
Massive-bedded bluish tough calcareous and argillaceous sandstone with fossiliferous calcareous layers	25
Gray sandstone, weathering brown	5
Shaly earthy contorted sandy limestone	31
Hard thick-bedded bluish calcareous sandstone	20
Softer shaly earthy sandstone	30
Thick bed of earthy sandstone	6
Hard impure limestone, with chert nodules	8
Thick soft earthy sandstone	10
Shaly earthy limestone	60
Thick-bedded to shaly earthy sandstone	45
Covered, probably some red shale, shaly earthy limestone, and soft earthy sandstone	225±
Red shaly sandstone and shale, mottled yellow	10
Red shale in part, rest covered	25
Red shaly sandstone, mottled yellow	7
Shaly gray sandstone, with phosphatic fish plates	10
Sandy shale, in part covered	20
Soft shale, light buff to dark drab; light-gray fire clay with rootlets, leaves, and twigs at base	20
Black coaly fissile shale	1
Slabby blue even-grained irregular-bedded sandstone, weathering buff (top of Price sandstone).	

The next best partial section is just east of Watson Gap, 2 miles southwest of Broad Ford, which is as follows:

Partial section of Maccrady formation east of Watson Gap, Va.

	Thickness
	Feet.
Thin-bedded earthy limestone, with some hard dense beds	30
Purple fissile shale, with some earthy limestones	14
Fissile red shale	10
Micaceous red sandstone, mottled yellow	4
Fissile and crumbly red shale, mottled yellow	37
Hard yellow and red agglomeratic shale	1
Crumbly red sandstone and some yellow shale	10
Harder red sandstone, in part shaly	4
Red argillite and shale, with drab sandy concretionary masses	3
Greenish fire clay, with rootlets, red at surface	2
Crumbly and fissile red and yellow shale	30
Soft greenish micaceous sandstone, purplish at top	20
Soft yellow shale	4
Black fissile coaly shale	3
Thin sandstone and fire clay, with rootlets	1
Greenish fissile shale	10
Thin irregular-bedded sandstone	8
Sandy light-buff fire clay, with rootlets	3
Covered, probably thin sandstone and shale	10
Massive-bedded greenish-gray calcareous sandstone (top of Price sandstone).	

Just east of Broad Ford is another fair exposure that shows the relations of the gypsiferous shales to the rest of the formation:

Partial section of Maccrady formation east of Broad Ford, Va.

		Thickness
		Feet.
Soft red and green shale and clay, with some soft thick brown sandstone and earthy limestone	Weather or change laterally into gypsum-bearing red plastic clays with secondary limestone layers	150
Red and green shale		
Red rippled sandstone		
Gray shale with red sandstone bed		
Red shale and sandstone		
Gray shale		
Thin black fissile coaly shale		1
Earthy limestone and calcareous shale		12
Covered, probably in part soft earthy limestone		40+
Red sandstone and sandy shale (with unexposed gray sandstone, shale, and carbonaceous seams to base of formation), estimated		130±

From the relations observed in the northeastern part of the area it may be stated that the gypsum does not occur in the lower red siliceous beds of the formation and probably not lower than 180 feet from the base; that thin-bedded argillaceous limestones which are characterized by a small spirifer resembling *S. bifurcata* generally occur near the top of this barren interval; that the gypsum seems to replace certain soft earthy sandstones, shales, and limestones in the overlying portion of the formation present in that part of the area.

Southwest of Saltville, where the surface exposures do not show the relations of the gypsum, the well records also do not aid much in their solution. From a glance at the records of the Mathieson Alkali Co.'s borings, kindly permitted by Mr. W. D. Mount, manager of the plant, no clue was gained as to the sequence of the gypsum and salt beds or of their relation to recognizable limestone, sandstone, or hard red sandy beds. The basal barren sandy beds were not observed, even in the deepest well. A generalized record of one of the typical wells of the Mathieson Co. illustrates the relative distribution of the gypsum and salt which prevails throughout most of the sections.

Generalized section of a well at Saltville, Va.

	Thickness	Depth
	Feet	*Feet*
Limestone and shale	26	26
Shale and gypsum	195	221
Mostly shale with gypsum and some rock salt	359	580
Mostly limestone with shale, gypsum, and rock salt	215	795
Mostly shale with gypsum and rock salt	100	895
Mostly rock salt with little shale	197	1,092

The record of a well on the Buena Vista Plaster Co.'s property at Plasterco, as given by T. L. Watson, is as follows:

Section of well at Plasterco, Va.

	Thickness	Depth
	Feet	*Feet*
Red clay	10	10
Clay and plaster	6	16
Impure plaster	34	50
Pure plaster	52	102
Slate and plaster	63	165
Nearly all plaster	45	210
Blue slate	110	320
Blue slate and plaster	70	390
Yellow soapstone	55	445
Pure plaster	45	490
Red rock with little salt	15	505

The distribution of gypsum throughout several hundred feet of strata in the wells at Saltville and Plasterco indicates that, even if the beds have a relatively steep dip, the gypsum has a wide vertical range in the southwestern part of the area and may replace higher beds in the formation than occur at the surface in the northeast.

Conclusions.

It can not be determined positively from the well records whether the deposits are in thick continuous beds or, as has been found to be the condition in the mines at Plasterco, in detached segregated masses. The distinct interbedding, however, of the gypsum with limestone, shale, red clay, and rock salt in the Saltville wells precludes the idea that the deposits were formed in wash from the surrounding higher areas into a trough or lake, as suggested by Stevenson. The gypsum beds have nowhere been mined deep or far enough to determine how they change laterally into other sedimentary rocks. This must be inferred from such facts as can be gathered in the mines, on the surface, and in the well records.

The conclusion expressed by Eckel that the deposits are strictly sedimentary in origin, having been derived from the evaporation of confined bodies of water under salt-pan conditions, is believed by the writer to be only partly correct. The fact that the beds of almost solid gypsum 50 to 100 feet in thickness vary greatly, occurring at intervals along the belt of these rocks, with barren areas between, and, so far as known, not at all on the northwest side of the syncline away from the fault, does not harmonize with this view. That salt-pan conditions could be so local and still persist for so long a time as to form such thick beds of gypsum and that these conditions could be repeated over and over again in the same place while not occurring at all in intervening areas is highly improbable.

The facts that the gypsum is segregated in workable deposits in the Maccrady formation at intervals along a fault contact, with barren areas between, and that none occurs in the same formation, so far as known, where not adjacent to the fault, are more reasonably explained by assuming, first, that gypsum was originally deposited as disseminated grains and innumerable thin leaves with argillaceous and calcareous silt and earthy sand of the Maccrady formation in a partly inclosed arm of the sea, at times subjected to intense evaporation; second, that the gypsum was later concentrated in the same formation by ground waters, which, circulating along the fault, dissolved part of the disseminated calcium sulphate and redeposited it in adjacent gypsiferous beds, the gypsum being segregated

by chemical selection. The calcium carbonate in the calcareous silt was likewise dissolved by the meteoric waters and the gypsum has taken its place, possibly by direct replacement, the waters, being carbonated, dissolving the calcium carbonate and depositing the calcium sulphate.

A sample of unaltered earthy limestone from the horizon of the gypsum-bearing clays of the Maccrady formation near Broad Ford was analyzed for F. A. Wilder, president of the Southern Gypsum Co., and was reported to contain 4 per cent of $CaSO_4$. Another sample from the limestone quarry across the river from the Mathieson Alkali works, analyzed in the chemical laboratory of the U. S. Geological Survey, showed 3.16 per cent of $CaSO_4$ present. This may represent the amount of disseminated gypsum present in the original calcareous silt.

In addition to the facts mentioned above pointing to this conclusion, several other observations may be cited. The occurrence of large crystalline sheets of selenite in the granocrystalline mass and especially of small veinlets of satin spar in the otherwise barren inclosing clay, affords positive proof that solution and redeposition may have taken place to some extent. The massive gypsum has the appearance of bedding, due to the banding of gray impurities, but on close observation this is found to be not sedimentary banding parallel to the inclosing strata but concentric banding parallel to inclosed bodies of "black rock," fine particles of the argillaceous material producing the dark banding. These argillaceous masses may have resulted from less soluble clayey masses in an otherwise calcareous gypsiferous bed which was gradually encroached upon during the concentration of the gypsum and particles of it were left as banded impurities in the gypsum; similar drab argillaceous concretionary masses were observed in the red argillite 94 feet above the base of the Maccrady formation on the road east of Watson Gap. Or, on the other hand, the argillaceous impurities may have been segregated in the rounded masses by chemical repulsion during the concentration and purification of the gypsum. At least, both the banding of the gypsum and the rounded masses of argillaceous "black rock" appear to have resulted from the secondary segregation of the gypsum. The red plastic clay that generally incloses the gypsum is probably the fine argillaceous impurity of the earthy limestone left as a residuum, expelled by the crystalline segregation of the gypsum, and stained red by contained iron highly oxidized when set free during the process. Thin layers of fine-grained limestone in the gypsiferous clays were apparently redeposited from solution as another secondary mineral.

This theory as to the method of the concentration of gypsum is not new, for it has been proved beyond much doubt that the remarkable domes

of salt and gypsum in Louisiana and Texas were formed by the deposition of these minerals along spring lines at the exposed intersection of fissures or faults,[a] having been dissolved and transported from some deeper-lying beds. Secondary limestone, apparently similar to the crackled layers in the clays of the Holston Valley area, also occur in the domes associated with the salt and gypsum. The fact that the Louisiana deposits were derived from lower beds suggests the possibility that the salt and gypsum in the Holston Valley area were also derived from beds at a lower horizon, that the solutions rose along the fault, and that these minerals were deposited at or near the surface in their present position. This explanation, however, is untenable, inasmuch as none of the older formations which outcrop to the west on the slopes of Clinch Mountain—not even the representative of the Salina, the great salt and gypsum bearing formation of New York—contain deposits from which these minerals could have been derived, and furthermore, as such strictly secondary deposits would be found only at or near the surface, whereas the Holston Valley deposits occur interbedded in the Maccrady formation to considerable depths.

If the theory of secondary concentration above suggested is the correct explanation of the origin of the gypsum in the Holston Valley area, it accounts for the absence of the mineral in quantity on the west side of the syncline away from the fault, the occurrence of natural outcrops of gypsum close to the fault, and the greater thickness of the deposits toward the southeast, as developed by borings in the Saltville, Plasterco, North Holston, and other tracts tested. In accordance with this theory it may be predicted that the gypsum will be found to extend under the overthrust Cambrian dolomite as far as the Maccrady formation is at the fault contact, and when the deposits near the surface are worked out deeper mining may be carried in this direction.

The beds of rock salt undoubtedly had the same origin as the gypsum and may be regarded as concentrations of somewhat saliferous beds, the associated calcium carbonate of the earthy limestone being dissolved out and its place taken by salt, segregated by solution and redisposition through chemical selection. Whether workable beds will be found associated with all the gypsum deposits can not at present be determined, but where salt has not been encountered in mining the gypsum there is still a prospect that it may be discovered at greater depth close to or under the overthrust dolomite. This is especially true southwest of Saltville,

[a]Harris, G. D., Rock salt: Bull. Louisiana Geol. Survey No. 7, 1907; Oil and gas in Louisiana: Bull. U. S. Geol. Survey No. 429, 1910.

where the overriding Cambrian limestone conceals most of the Maccrady formation, as it is apparently turned under in a minor anticline next to the fault. Southwest of Plasterco both salt and gypsum may be expected along the fault some distance from its outcrop under the overthrust mass where the Maccrady formation is probably at the fault contact. This may be proved by either drilling through an unknown thickness of tough dolomite southeast of the fault or boring diagonally under it in the soft rocks at the fault contact.

SUMMARY.

The gypsum and salt deposits of southwestern Virginia described in this report are believed by the writer to have been derived from calcareous-argillaceous sediments which originally contained disseminated gypsum and salt precipitated in a partly inclosed arm of the sea during the deposition of the Maccrady formation, these minerals having been concentrated in the same formation by ground waters which circulated along the fault contact between the Carboniferous and Cambrian rocks, dissolved the calcium carbonate from the earthy limestones, and segregated the gypsum and salt in the gypsiferous and saline beds by chemical selection.

INDEX